Full Length Research Paper

The effects of dietary supplementation of tomato peel ultrafine powder on glycemic response in streptozotocin-induced diabetic rats and blood lipids in high-fat diet rats

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This study was designed to investigate the effects of dietary supplementation of tomato peel ultrafine powder (TPUP) on glycemic response in streptozotocin (STZ)-induced diabetic rats and blood lipids in high-fat diet rats. STZ-induced diabetic rats and high-fat diet rats were administrated orally with TPUP for 21 and 49 days and subjected to biochemical analysis of blood glucose and lipids profiles, respectively. Compared with diabetic control rats, STZ-induced diabetic rats treated with TPUP for 3 weeks had significantly (P<0.05) increased level of body weight and decreased levels of fasting blood glucose, insulin and C-peptide by 39.9, 51 and 17.1% in high dose (1.0 g kg⁻¹bw) group and 32.8, 38.8 and 22.9% in low dose (0.2 g kg⁻¹bw) group, respectively. Besides a dramatically decrease (P<0.05) in total cholesterol level up to 32.6% obtained in high dose (1.0 g kg⁻¹bw) group, no significant changes were observed with triglycerides, high-density lipoprotein cholesterol and low-density lipoprotein cholesterol levels with TPUP treated high-fat diet rats, as compared to those index of high-fat diet control rats. These findings suggest that TPUP might be fabricated as an additive of functional foods because of its potential antihyperglycemic and hypolipidemic effects in STZ-induced diabetic rats and high-fat diet rats.

Key words: Tomato pomace, tomato peel ultrafine powder, STZ-induced diabetic rats, hypoglycemic effect, hypolipidemic effect.

INTRODUCTION

Since there is no medication that can eradicate diabetes and side effects of drugs, researchers around the world are devoting efforts to extracting functional ingredients from natural plants to bring about antihyperglycemic and hypolipidemic effect, particularly in some Asian countries (Chuang et al., 2008). Tomato-processing by-product called tomato pomace consists of peel and seeds, and represents around 4% of the fruit weight (Del Valle et al., 2006). Most tomato pomace are used as animal feed, example for sheep and poultry. Meanwhile, because it contains 59.03% fiber, tomato pomace is also a kind of
good source of dietary fiber (Alvarado et al., 2001). As raw material, dry tomato peel can be extracted to produce lycopene (Calvo et al., 2007) and can also be back-added into tomato paste (Reboul et al., 2005). Hamburger (Luisa Garcia et al., 2009), snack (Altan et al., 2008) and fermented sausage (Calvo et al., 2008) to increase nutritional value.

It is reported that regular consumption of tomato products has been associated with decreased risk of chronic degenerative diseases (Basu and Imrhan, 2007). Daily intake of lycopene at a dose of 90 mg kg⁻¹ bw could lower the level of serum free radical in streptozotocin (STZ)-induced hyperglycemic rats (Ali and Agha, 2009) and inhibit platelet aggregation in type 2 diabetes (Lazarus et al., 2004). Consumption of commercial tomato juice increased plasma lycopene level and the intrinsic resistance of low density lipoprotein (LDL) to oxidation, and a risk for myocardial infarction also decreased in patients with diabetes (Upritchard et al., 2000). Dietary fiber of tomato residue diminishes glucose absorption and reduces serum cholesterol levels, which in turn could be useful in the treatment of non-insulin-dependent diabetes (NIDD) and hypercholesterolemic patients (Alvarado et al., 1999; Rafiq et al., 2009). A high dietary intake of tomato products has atheroprotective effects by significantly reducing levels of liver cholesterol and serum cholesterol (Pourkabir et al., 2010). Fermented milk supplement containing tomato might play an important role in blood lipid profiles improvement in postmenopausal hyperlipidemic model rats (Chang and Cheong, 2007) and the tomato diets with steroidal glycoalkaloid tomatine induced lowering of serum low density lipoprotein cholesterol (LDL-C) without changing high density lipoprotein cholesterol (HDL-C) (Ogbonnia et al., 2008).

Ultrafine grinding technology was found to improve the function of dietary fiber (Zhu et al., 2010) and due to lack of reports on tomato peel ultrafine powder (TPUP) in retrieved literature, the TPUP was selected to be test sample in this study, and also for the reason that TPUP is easy to administer orally in rats. The effect of TPUP on glycemic response in STZ-induced diabetic rats and blood lipids in high-fat diet rats were investigated in this experiment, and we hope that the findings would help us to understand the impact of TPUP on rats with hyperglycemia and hyperlipidemia, and to seek a better solution by developing functional products using tomato peel in the future.

MATERIALS AND METHODS

Chemicals and animal feed

STZ was bought from Sigma-Aldrich Co. (USA). The kits for the measurement of insulin, C-peptide and glycosylated serum protein (GSP) were purchased from Regobio Tech Inc. (Shanghai, China) and kit for the measurement of lipids profile (TC, TG, and HDL-C) were purchased from Jingma Bio-tech Inc. (Wenzhou, China). All solvents used in this study were of analytical grade.

The ingredients of standard diet were prepared in accordance with requirements of GB 14924.3-2001. The high-fat diet was produced according to the following formula: standard diet, 740 g kg⁻¹; lard, 100 g kg⁻¹; yolk powder, 100 g kg⁻¹; whole milk powder, 50 g kg⁻¹; cholesterol, 10 g kg⁻¹; sodium cholate, 1 g kg⁻¹.

Experimental animals

Male Sprague Dawley rats (170-210 g) were procured from the Animal Center of Third Military Medical University (Chongqing, China). The rats were acclimatized under controlled room temperature (22±2°C) and humidity (40±60%) with 12 h light and 12 h dark cycle, and given a standard diet and water ad libitum for 7 days prior to the commencing experiment. The guidelines of committee for the purpose of control and supervision of experiments on animals (CPCSEA), Government of China were followed and prior permission was sought from the institutional Animal Ethics Committee for conducting this study.

Induction of diabetes in rats

The animals were injected intraperitoneally with a single dose of 55 mg kg⁻¹ bw STZ dissolved freshly in cold 0.1 M citrate buffer adjusted to pH 4.5 after 12 h fasting (Park et al., 2001). The fasting blood glucose was measured 5 days later using a glucometer (YiCheng Bio-electronic Co., Ltd, Beijing, China) to confirm their diabetic stage. The rats with fasting blood glucose (FBG) level higher than 11.1 mmol L⁻¹ were selected as diabetic ones and used for hypoglycemic experiment.

Preparation of TPUP

The tomato peel was separated by water floatation from tomato pomace provided by a tomato processing factory (Xinjiang Tianye Co., Ltd). After being dried in oven at 60°C for 12 h, the peel was powdered through 100 mesh and then the powder was processed with an ultrafine grinder (BFM-T681, Billion Powder TEC&ENG Co., Ltd, Jinan, China) for 15 min at -10°C to obtain the tomato peel ultrafine powder (TPUP). The proximate composition analysis indicated TPUP consists of 147.1 g kg⁻¹ protein, 62.5 g kg⁻¹ lipid, 29.4 g kg⁻¹ starch, 40.6 g kg⁻¹ ash and 696.0 g kg⁻¹ dietary fiber. The particle size (D50, 40.66 μm) of TPUP was measured by Laser Particle Size Analyzer (OMEC Technology Co., Ltd, Zuhuai, China).

Experimental design

In the whole study, a total of 64 rats (34 normal, 30 STZ-induced diabetic rats) were used and divided into 8 groups (Groups 1 to 8). Group 1 was set as normal control group (NC-D) for hypoglycemic experiment consisting of 10 normal rats. The 30 STZ-induced diabetic rats were divided into three groups (Groups 2 to 4) of 10 rats in each, namely diabetic control group (DC), high dose TPUP (1.0 g kg⁻¹ bw) treatment diabetic group (D+HT) and low dose TPUP (0.2 g kg⁻¹ bw) treatment diabetic group (D+LT). The other 24 normal rats were randomly divided into four groups (Groups 5 to 8) of 6 rats in each, namely normal control group (NC-HF) for hyperlipidemic experiment, high-fat diet control group (HFC), high dose TPUP (1.0 g kg⁻¹ bw) treatment high-fat diet group (HF+HT) and low dose TPUP (0.2 g kg⁻¹ bw) treatment high-fat diet group (HF+LT).

All rats were given the standard diet and water ad libitum besides...
specified high-fat diet groups, and animals were administered orally once daily according to following recipe. NC-D: 2 ml 2 g L⁻¹ sodium alginate; DC: 2 ml 2 g L⁻¹ sodium alginate; D+HT: 0.2 g TPUP suspended in 2 ml 2 g L⁻¹ sodium alginate; DC: 2 ml 2 g L⁻¹ sodium alginate; NC-HF: 2 ml 2 g L⁻¹ sodium alginate; HFC: 2 ml 2 g L⁻¹ sodium alginate and high-fat diet; HF+HT: 0.2g TPUP suspended in 2 ml 2 g L⁻¹ sodium alginate and high-fat diet; HF+LT: 0.04g TPUP suspended in 2 ml 2 g L⁻¹ sodium alginate and high-fat diet.

**Table 1.** Effect of administering tomato peel ultrafine powder on body weight (g) in streptozotocin-induced diabetic rats.

<table>
<thead>
<tr>
<th>Group</th>
<th>0 day</th>
<th>7 day</th>
<th>14 day</th>
<th>21 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC-D</td>
<td>195 ± 4.2Aa</td>
<td>207.3 ± 5.2Aa</td>
<td>224.2 ± 7.2Ab</td>
<td>237.8 ± 9.2Ab</td>
</tr>
<tr>
<td>DC</td>
<td>174.3 ± 6.8Aa</td>
<td>160.9 ± 8.0Ba</td>
<td>162.5 ± 7.8Ba</td>
<td>162.5 ± 7.2Ba</td>
</tr>
<tr>
<td>D+HT</td>
<td>187.3 ± 6.9Aa</td>
<td>192.5 ± 10.7Aa</td>
<td>216.3 ± 12.2Aa</td>
<td>222 ± 16.3Aa</td>
</tr>
<tr>
<td>D+LT</td>
<td>174.9 ± 8.1Aa</td>
<td>172.8 ± 8.2Ba</td>
<td>162.5 ± 9.6Ba</td>
<td>151 ± 14.6Ba</td>
</tr>
</tbody>
</table>

Different lowercase letters (a, b) indicate significant difference at P<0.05 within group, and different capital letters (A-C) indicate significant difference on the same day at P<0.05 between groups. NC-D, Normal control group; DC, diabetic control group; D+HT, high dose TPUP treatment diabetic group; D+LT, low dose TPUP treatment diabetic group.

**RESULTS**

**Body weight and fasting blood glucose**

Table 1 shows that there was no significant difference in body weight between diabetic groups and NC-D group on day 0. However, on day 21, the body weight of rats in NC-D group increased significantly from 195±4.2 to 237.8±9.2 g, but those of DC and D+LT groups decreased remarkably from 174.3±6.8 and 174.9±8.1 g to 162.5±7.2 and 151±14.6 g, respectively. Still, there was no significantly difference found between D+HT group and NC-D group.

Moreover, significant difference in serum FBG level was found between diabetic groups and NC-D group on day 0 (Table 2). After 21 days supplementation with TPUP, FBG level in D+LT group had no significant change compared to that of DC group. However, remarkable decrease was observed (lower 56.7 and 69.8% compared to day 0 and DC on day 21) in D+HT group and there was no significant difference compared with NC-D group.

**Serum insulin, C-peptide and glycosylated serum protein**

As shown in Figures 1 to 3, after TPUP supplementation for 3 weeks, serum insulin, C-peptide and GSP levels decreased by 39.9, 51 and 17.1% in D+HT group and 32.8, 38.8 and 22.9% in D+LT group compared to DC group. Significant difference in insulin and C-peptide levels was found between TPUP group and DC group, and no significant difference in GSP levels was found between D+HT and DC group.

**Pancreatic islet**

The effects of TPUP in histopathological examination are shown in Figure 4. Compared with normal control rats
Table 2. Effect of administering tomato peel ultrafine powder on fasting blood glucose (mmol L\(^{-1}\)) levels in streptozotocin-induced diabetic rats.

<table>
<thead>
<tr>
<th>Group</th>
<th>0 day</th>
<th>7 day</th>
<th>14 day</th>
<th>21 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC-D</td>
<td>7.2 ± 0.2(^{Aa})</td>
<td>7.1 ± 0.2(^{Aa})</td>
<td>7.2 ± 0.3(^{Aa})</td>
<td>6.7 ± 0.2(^{Aa})</td>
</tr>
<tr>
<td>DC</td>
<td>19.6 ± 1.1(^{Bb})</td>
<td>16.8 ± 2.5(^{Bb})</td>
<td>20.3 ± 2.1(^{Bb})</td>
<td>24.5 ± 1.9(^{Cb})</td>
</tr>
<tr>
<td>D+HT</td>
<td>17.1 ± 1.5(^{Bb})</td>
<td>11.1 ± 2.5(^{ABab})</td>
<td>12.9 ± 3.3(^{ABab})</td>
<td>7.4 ± 1.1(^{Aa})</td>
</tr>
<tr>
<td>D+LT</td>
<td>17.9 ± 1.4(^{Bb})</td>
<td>14 ± 2.0(^{ABb})</td>
<td>16.4 ± 2.1(^{Bb})</td>
<td>16.5 ± 5.8(^{BCb})</td>
</tr>
</tbody>
</table>

Different lowercase letters (a, b) indicate significant difference at \(P<0.05\) within group, and different capital letters (A-C) indicate significant difference on the same day at \(P<0.05\) between groups. NC-D, Normal control group; DC, diabetic control group; D+HT, high dose TPUP treatment diabetic group; D+LT, low dose TPUP treatment diabetic group.

Figure 1. Effect of tomato peel ultrafine powder on serum insulin level in streptozotocin-induced diabetic rats.

(A), degenerative changes and islet cell necrosis in endocrine pancreas such as decreased number and size of pancreatic islets, ambiguity of their verges and invasion of connective tissues was observed in DC rats (B). Whereas, after treated with TPUP, increased number of islets and improved islet shape indicated amelioration in histological signs; pancreatic islets maintained better morphology (C, D) compared with islet of diabetic control rat (B). This evidence further proved the point mentioned earlier that TPUP supplementation might have a repaired effect on damaged pancreatic islet, although the reason is still unclear to us. The results also showed that recovery of pancreatic islet from high dose of TPUP intake (C) is better than low dose (D), but did not reach to the normal level (A).

Blood lipids

The effect of TPUP treatment on blood lipid levels of the tested rat groups is given in Table 3 (a-d). The results show that consumption of TPUP for 7 weeks did not significantly alter TG level (Table 3b) in serum, and on day 49, there was a negative but not significant effect (\(P>0.05\)) on HDL-C (Table 3c) compared to HFC group. However, the level of TC was significantly lower than
DISCUSSION

Type 2 diabetes and its long-term complications are a major cause of morbidity and mortality worldwide and the prevalence of the disease continues to rise. And FBG concentration is a very important target need to be controlled for Diabetic patients (Balkau et al., 1998). As shown in Tables 1 and 2, on day 21, remarkable increase in body weight and decrease in FBG level was found with high dose of TPUP supplementation in diabetic rats, and there was significant difference in both of FBG and bodyweight between D+HT group and DC group.

Figure 2. Effect of tomato peel ultrafine powder on serum C-peptide level in streptozotocin-induced diabetic rats.

Figure 3. Effect of tomato peel ultrafine powder on serum glycosylated serum protein level in streptozotocin-induced diabetic rats.

high-fat control by 32.6% with high dose of TPUP treatment for 7 weeks.
However, no significant difference was observed between D+HT group and NC-D group. The findings indicate that TPUP supplementation could inhibit effectively the rise in serum insulin and C-peptide by the corresponding enzyme, serum insulin and C-peptide could serve as indicators of reflecting the capacity of insulin secretion, and C-peptide could reflect the β-cell function more accurately because it was not affected by exogenous insulin. In this experiment, insulin and C-peptide level was increased significantly in DC group (Figures 1 and 2), which may be caused by insulin resistance (Reaven, 1988). The reason is perhaps related with the timing of blood sample collected from different period of diabetic rats. Insulin and C-peptide levels decreased to a level close to the NC-D group with the TPUP supplementation; this implied that TPUP might have a therapeutic effect on repairing damaged beta cell function. In addition, GSP could reflect the overall blood glucose level in longer-term (2 to 3 weeks). As shown in Figure 3, there was a significant difference between NC-D group and DC group, but no significant difference was found within diabetic rats group. This result shows that effect of TPUP in blood glucose level for longer-term less than the effect for shorter-term, indicating that longer-term TPUP supplementation may be limited for improving the condition of diabetic rats.

It is well recognized that high levels of serum TC and LDL-C are associated with an increased risk of coronary artery disease (CAD) (Verschuren et al., 1995). After high dose TPUP supplementation for 49 days, a significant decrease was observed between HF+HT group and HFC group (Table 3a), indicating that supplementation of long-term and high dose TPUP could effectively reduce serum TC level in high-fat diet rats. This is possibly attributed to the enhanced fermentability of dietary fiber by size reduction. The increase of HDL-C and reduction of LDL-C is the primary goal for treatment of hyperlipidemia, and LDL-C is presently the primary focus clinically of lipid-lowering therapy (Chapman et al., 2004). In this study, on day 49, LDL-C level was decreased in HF+HT and HF+LT groups, although no significant difference was observed compare with HFC group (Table 3d). Overall, for lipid-lowering effect on tomato, the findings of this

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**Table 3. Effect of administering tomato peel ultrafine powder on lipids profile levels (mmol L⁻¹) in high-fat diet rats**

<table>
<thead>
<tr>
<th>Group</th>
<th>0 day</th>
<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>49 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC-HF</td>
<td>1.92 ± 0.03&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>2.49 ± 0.18&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>1.96 ± 0.29&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>1.63 ± 0.06&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>1.61 ± 0.10&lt;sup&gt;Aa&lt;/sup&gt;</td>
</tr>
<tr>
<td>HFC</td>
<td>1.98 ± 0.06&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>3.00 ± 0.24&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>4.47 ± 0.16&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>3.74 ± 0.41&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>5.16 ± 0.47&lt;sup&gt;ABb&lt;/sup&gt;</td>
</tr>
<tr>
<td>HF+HT</td>
<td>1.80 ± 0.07&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>2.09 ± 0.26&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>4.02 ± 0.36&lt;sup&gt;Ac&lt;/sup&gt;</td>
<td>2.90 ± 0.35&lt;sup&gt;ABabc&lt;/sup&gt;</td>
<td>3.48 ± 0.32&lt;sup&gt;ABabc&lt;/sup&gt;</td>
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<tr>
<td>HF+LT</td>
<td>1.79 ± 0.05&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>3.28 ± 0.03&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>4.14 ± 0.41&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>3.29 ± 0.01&lt;sup&gt;ABb&lt;/sup&gt;</td>
<td>4.26 ± 0.43&lt;sup&gt;ABb&lt;/sup&gt;</td>
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**TG**

<table>
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<tr>
<th>Group</th>
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<th>12 day</th>
<th>24 day</th>
<th>36 day</th>
<th>49 day</th>
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<tr>
<td>NC-HF</td>
<td>0.54 ± 0.02&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>0.60 ± 0.02&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.67 ± 0.03&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.34 ± 0.01&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.56 ± 0.07&lt;sup&gt;ABab&lt;/sup&gt;</td>
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<tr>
<td>HFC</td>
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<td>0.46 ± 0.13&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.44 ± 0.02&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.46 ± 0.02&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.45 ± 0.05&lt;sup&gt;ABab&lt;/sup&gt;</td>
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<tr>
<td>HF+HT</td>
<td>0.64 ± 0.04&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>0.49 ± 0.08&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.93 ± 0.34&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.52 ± 0.16&lt;sup&gt;ABab&lt;/sup&gt;</td>
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<td>HF+LT</td>
<td>0.58 ± 0.04&lt;sup&gt;Aa&lt;/sup&gt;</td>
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<td>0.92 ± 0.12&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.86 ± 0.21&lt;sup&gt;ABab&lt;/sup&gt;</td>
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**HDL-C**

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<th>Group</th>
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<th>24 day</th>
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<tr>
<td>NC-HF</td>
<td>0.98 ± 0.07&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>1.25 ± 0.01&lt;sup&gt;ABa&lt;/sup&gt;</td>
<td>0.64 ± 0.14&lt;sup&gt;ABa&lt;/sup&gt;</td>
<td>1.10 ± 0.06&lt;sup&gt;ABa&lt;/sup&gt;</td>
<td>0.93 ± 0.11&lt;sup&gt;ABa&lt;/sup&gt;</td>
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<tr>
<td>HFC</td>
<td>1.18 ± 0.04&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>1.24 ± 0.04&lt;sup&gt;ABa&lt;/sup&gt;</td>
<td>1.37 ± 0.10&lt;sup&gt;ABa&lt;/sup&gt;</td>
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<tr>
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<td>1.07 ± 0.07&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>1.15 ± 0.12&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.90 ± 0.04&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>0.66 ± 0.09&lt;sup&gt;ABab&lt;/sup&gt;</td>
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<tr>
<td>HF+LT</td>
<td>1.02 ± 0.03&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>1.40 ± 0.05&lt;sup&gt;ABa&lt;/sup&gt;</td>
<td>1.06 ± 0.13&lt;sup&gt;ABa&lt;/sup&gt;</td>
<td>0.97 ± 0.01&lt;sup&gt;ABa&lt;/sup&gt;</td>
<td>0.59 ± 0.08&lt;sup&gt;ABa&lt;/sup&gt;</td>
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**LDL-C**

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<tr>
<td>NC-HF</td>
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<td>3.02 ± 0.26&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>2.50 ± 0.41&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>4.36 ± 0.44&lt;sup&gt;ABab&lt;/sup&gt;</td>
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<td>HF+HT</td>
<td>0.70 ± 0.05&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>0.92 ± 0.20&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>2.69 ± 0.51&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>1.90 ± 0.42&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>3.36 ± 0.39&lt;sup&gt;ABab&lt;/sup&gt;</td>
</tr>
<tr>
<td>HF+LT</td>
<td>0.70 ± 0.07&lt;sup&gt;Aa&lt;/sup&gt;</td>
<td>1.81 ± 0.02&lt;sup&gt;ABab&lt;/sup&gt;</td>
<td>2.97 ± 0.55&lt;sup&gt;ABab&lt;/sup&gt;</td>
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<td>3.50 ± 0.43&lt;sup&gt;ABab&lt;/sup&gt;</td>
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</tbody>
</table>

Different lowercase letters (a-c) indicate significant difference at <i>P</i>≤0.05 within group, and different capital letters (A-C) indicate significant difference on the same day at <i>P</i>≤0.05 between groups. NC-HF, Normal control group (NC-HF) for hypolipidemic experiment; HFC, high-fat diet control group; , HF+HT, high dose TPUP treatment high-fat diet group; HF+LT, low dose TPUP, treatment high-fat diet group; TC, total cholesterol; TG, triglyceride; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol.

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study supported previous results (Silaste et al., 2007; Alvarado et al., 1999; Chang et al., 2007).

Conclusion

TPUP supplementation could bring about antihyperglycemic and cholesterol-lowering effects and the findings obtained herein revealed that long term TPUP supplementation could inhibit elevation of FBG level in diabetic rats and TC level in high-fat diet rats. These findings suggest that TPUP might have some potential antihyperglycemic and cholesterol-lowering effects in STZ-induced diabetic rats and hyperlipidemic rats. However, we were not certain whether the impacts came from lycopene or dietary fiber or both; hence further study should be focused on the mechanism of blood glucose-lowering and lipid-lowering with TPUP supplementation.

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Abbreviations

ANOVA, Analysis of variance; bw, body weight; CAD, coronary artery disease; DC, diabetic control; DM, diabetes mellitus; DTP, dry tomato peel; FBG, fasting blood glucose; GSP, glycosylated serum protein; HDL-C, high density lipoprotein cholesterol; HFC, high-fat control; TPUP, tomato peel ultrafine powder; HT, high dose of TPUP; LDL-C, low density lipoprotein cholesterol; LT, low dose of TPUP; NC-D, normal control for diabetic rats; NC-HF, normal control for high-fat rats; NIDD, non-insulin-dependent diabetes; PBG, postprandial blood glucose; SPF, specific pathogen free; STZ, streptozotocin; T2DM, type 2 diabetes mellitus; TC, total cholesterol; TG, triglycerides; VDL-C, very-low-density lipoprotein cholesterol.

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