# Hypoglycemic and Antioxidative Effects of Fermented Chaga Mushroom (*Inonotus obliquus*) on Streptozotocin-induced Diabetic Rats

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The effects of fermented chaga mushroom (*Inonotus obliquus*) on the concentrations of serum glucose, insulin, lipids and lipid peroxidation in streptozotocin (STZ)-induced diabetic rats were investigated. Rats were fed a semisynthetic diet supplemented with 50 g/kg chaga mushroom powder (the CM group) and fermented chaga mushroom powder (the FCM group), and no supplemented (the control group) for 3 weeks. The polysaccharide concentrations were CM by 42.9% and FCM by 39.1%, and the total polyphenol concentrations were CM by 0.80% and FCM by 09.1%. Feed intakes and water consumption, serum glucose, insulin, triglyceride, and blood urea nitrogen concentrations were significantly lower in the FCM group than in both the CM and control groups. The activities of AST and ALT were also significantly lower in the FCM group than in the control group. No significant differences were detected with regard to the serum cholesterol and creatinine concentrations among the experimental groups. Lipid peroxidations in hepatic homogenate, microsomal and mitochondrial subcellular and pancreas were significantly lowered by the administration of FCM in the STZ-diabetic rats. Hepatic glutathione concentrations, which is closely associated with antioxidant system, was significantly higher in the FCM group than in the control group, indicating a marked effect of FCM administration on the endogenous antioxidant system. However, CM treatment showed a moderate antioxidative activity in the STZ-diabetic rats. Our results indicate that fermented chaga mushroom exert hypoglycemic and antioxidative effects in type 1 diabetes mellitus.

**Key words** – *Inonotus obliquus*, Chaga mushroom, diabetes mellitus, streptozotocin, hypoglycemia.

Mushrooms are a traditional oriental medicine and also used commonly as foods. Approximately 1,000 species of mushrooms exist in Korea, about 100 species of these have been used as edible or medicinal mushrooms. Mushrooms such as *Ganoderma lucidum, Lentinus edodes, Inonotus obliquus*, and many others have been collected and used in Korea, Chines and eastern Russia[8,12]. Recently, these mushrooms have been elucidated therapeutic effects including hypoglycemia[21,46], hypolipidemia[22], antitumor[8,33], antioxidation [9], and hypertension[40]. Edible mushrooms and products using these have also shown hepatoprotective effects against hepatic injuries in development of type 1 streptozotocin-induced diabetic rats and type 2 genetically Zucker diabetic rats and chemical-induced hepatic injury[18,47]. The pharmacological components of mushrooms with hypoglycemic action include polysaccharides, flavonoids, alkaloids, steroids, and terpenoids[21,33,49], which processed the hypoglycemic activities potentially by increasing the plasma insulin levels in diabetic animals[16,49].

Diabetes mellitus and diabetic complications are associated with high oxidative stress levels, resulting from an abnormalities in the antioxidant systems[31]. Increasing evidence from both experimental and clinical studies suggests that oxidative stress plays a major role in the pathogenesis of both type I and II diabetes mellitus. The antioxidative phenolics compound such as quercetin has been studied for the reversal of diabetic oxidative stress[39]. Phenolics compound in mushrooms contribute to the important antioxidant against diabetic oxidative stress. Edible mushrooms such as *Inonotus obliquus, Agaricus bisporus* (1.17~1.38%), *Lentinus edodes* (0.72%), *Volvariella volvacea* (0.81%) and *Flammulina velutipes* (0.78%) contains phenolics components such as hispolon and hispidin[5,25]. The main efficacious ingredients such as polysaccharides and phenolics component of *Inonotus obliquus* have been reported to have considerable antiviral [3] and antioxidative activities[17].

Oligosaccharides produces by enzymatically hydrolyzed from inulin, chicory, chitosan, and *Amorphophallus konjac*, which were also reported with hypoglycemic effects on di-

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abetic rats[26,30]. In our previous study, fermented chaga mushroom showed cytotoxic activity against cancer HCT-15 and AGS cell lines compared to chaga mushroom treatment[8]. However, the comparative hypoglycemic effect of chaga mushroom and fermented chaga mushroom on STZ-induced diabetic rats has not yet been studied. We therefore speculated that fermented chaga mushroom would been an ideal candidate for the hypoglycemic and antioxidative activities in diabetic animal experiment. The objective of the present study was to investigate the hypoglycemic and antioxidative effects of fermented chaga mushroom in STZ-induced diabetic rats.

## Methods and materials

### Crude polysaccharides and total polyphenolic concentrations of chaga mushroom

Dried fruiting bodies of chaga mushroom were powdered with a brander. Fermented chaga mushroom was prepared according to the previously reported method[8]. Crude polysaccharides from water-extracts of chaga mushroom or fermented chaga mushroom were prepared as described previously[34]. Crude polysaccharides in mushroom extract was precipitated by adding five volumes of ethanol. The resulting precipitate was collected by centrifugation, washed with ethanol. The concentration of crude water-soluble polysaccharides was determined by the phenol sulfuric acid method.

The total phenolics compounds were water-extracted and determined using Folin-Ciocalten phenol reagent (Sigma Chemical Com., St. Louis, MO) according to the procedure described by Coseteng and Lee[13]. To 2 mL mushroom extract solution, 2 mL of Folin-Ciocalten phenol reagent was added. The sample was mixed, and after 5 min, 2 mL of sodium carbonate solution (10%) was added, and then the mixture was shaken in darkness for 60 min at room temperature. The absorbance was measured at 700 nm using UV-visible spectrophotometer (Simadzu, Kyoto, Japan). Total phenolics content was calculated from a standard curve of tannic acid prepared at the same time.

### Animal and experimental design

Seven-week-old male Sprague-Dawley rats were purchased from Hyochang Science (Daegu, Korea), and housed individually in suspended wire-mesh stainless steel cages in a temperature-controlled animal room. Diabetes was induced in three groups with a single intraperitoneal injection of STZ (50 mg/kg body weight) dissolved in 0.05 M citrate buffer (pH 4.5). All diabetic rats had a blood glucose concentration higher than 400 mg/dL. The STZ-diabetic rats fed a semisynthetic control diet and fed a semisynthetic diets supplemented with 50 g/kg chaga mushroom powder or 50 g/kg fermented chaga mushroom powder. The composition of the semisynthetic diets was as follows (g/kg); starch 400, casein 200, sucrose 200, corn oil 100, cellulose 50, mineral mixture (AIN 93) 35, vitamin mixture (AIN 93) 10, DL-methionine 3, and choline bitartrate 2. The mushroom supplementation in the experimental groups was replaced with cellulose. The rats were allowed free access to the experimental diets and water for 3 weeks.

### Analytical procedure

At the end of the treatment period, the rats were sacrificed by abdominal aortic exsanguination, under light diethyl ether anesthesia, after a 12 hr fast. Livers and pancreas were quickly removed and weighed. Serum was separated by the centrifugation of the blood at 3,000 rpm for 15 min. The serum insulin concentration was measured with an immunoradiometric assay kit (Biosource, Urope S.A., Nivelles, Belgium). The concentrations of total cholesterol, triglyceride, creatinine, and blood urea nitrogen (BUN) the activities of alanine aminotransfrase (AST) and aspartate aminotransfrase (ALT) in serum were measured in the clinical laboratory of the Neodin Medical Institute (Seoul, Korea).

### Preparation of tissues homogenate and subcellular fractions

The preparation of tissues from individual rat was homogenized in ice-cold 0.25 M sucrose solution containing 10 mM Tris-HCl buffer (pH 7.4), 1 mM ethylenediamine tetraacetate (EDTA) in IKA-ULTRA-TURRAX T25 basic homogenizer (IKA-WERKE GMBH & CO. KG, Staufen, Germany). The hepatic microsomal and mitochondrial fractions were prepared as described previously[10]. Proteins were measured by the Lowry method using bovine serum albumin as a standard.

### Determination of lipid peroxidation (TBARS)

The concentrations of thiobarbituric acid reactive substances (TBARS) in hepatic subcellular fractional components and pancreas measured by the previously described method [42]. Reaction mixture containing tissues homogenate solution or each fractions and thiobarbituric acid (TBA) in-

cubated at boiling water for 30 min, and absorbance read at 532 nm using spectrophotometer (Simadzu, Kyoto, Japan). The concentrations of TBARS expressed as nanomoles of malondialdehyde (MDA).

### Determination of glutathione concentrations

Glutathione concentrations were determined by the method of Beutler and Kelly[7]. A 0.2 mL of liver homogenate was mixed with 1.8 mL of EDTA solution. To this reaction solution, 3.0 mL of precipitating reagent (1.67 g of metaphosphoric acid, 0.2 g of EDTA disodium salt, 30 g sodium chloride in 1 L of distilled water) was added, mixed thoroughly and kept for 5 min before centrifugation. After centrifugation 3,000 rpm for 5 min, to 2 mL of the supernatant, 4 mL of 0.3 M disodium hydrogen phosphate solution and 0.1 mL of 5,5'-dithiobis (2-nitrobenzoic acid)(DTNB) regent were added and glutathione concentration was spectophotometrically determined at 412 nm.

### Statistical analysis

The data from animal experiments are presented as the mean±SEM, and were analyzed using a one way analysis of variance (ANOVA), with the differences analyzed using the Duncan's new multiple-range test[14]. A $p$ value $<0.05$ was accepted as being a statistically significant difference.

## Result and discussion

### Crude polysaccharides and phenolics concentrations

Previous study has indicated that polysaccharides obtained from fruiting bodies of *Innotus obliquus* was consist of xylogalactoglucan[33,43]. The main components of this polysaccharides were composed of xylose and galactose. The yield of polysaccharides from *Innotus obliquus* was 31%[33]. Concentrations of crude polysaccharides were 42.9% in chaga mushroom and 39.1% in fermented chaga mushroom (Table 1).

Total polyphenolics concentrations of chaga mushroom and fermented chaga mushroom were 0.8% and 0.9%, respectively (Table 1), which were consistent with the amounts of total polyphenolics reported by Mau *et al.*[32] and Benoit *et al.*[5]. Lee and Jang reported[25] that total soluble phenolics were in the order of *Agaricus bisporus* (0.88%), *Volvariella volvacea* (0.81%), *Flammulina velutipes* (0.78%), *Lentinus edodes* (0.72%), and *Pleurotus ostreatus* (0.59%). *Innotus obliquus* contains phenolics components such as hispolon and hispidin[5]. It is our hypothesis that the main efficacious ingredients such as polysaccharides and phenolics conponents of *Inonotus obliquus* may be induce hypoglycemic and antioxidative effects on the STZ-diabetic rats.

### Body weight, food intake and water consumption

The body weight changes, food intake and water consumption are present in Table 2. There were no significant difference in the weights of body, liver and pancreas among the experimental groups. There have been reported that water consumption is generally higher in streptozotocin-induced diabetic rats[16] and genetically hyperglycemic KK-Ay mice[46] compared to their normal rats. In the present study, feed intakes and water consumption were significantly lower in the FCM group than in the control group. Previous

Table 1. Polysaccharides and phenolics component concentrations of chaga or fermented chaga mushrooms (*Inonotus obliquus*)

| | Polysaccharides | Phenolics component |
|---|---|---|
| Chaga mushroom (%) | 42.9 | 0.80 |
| Fermented chaga mushroom (%) | 39.1 | 0.91 |

Table 2. Body, hepatic and pancreatic weights, and feed intake and water consumption in the STZ-induced diabetic rats

| Ingredient | Control | CM | FCM |
|---|---|---|---|
| Body weight | | | |
| Initial(g) | 381.8±4.4$^{ns}$ | 378.0±10.4 | 404.7±11.4 |
| Final (g) | 381.4±6.8$^{ns}$ | 384.2±11.8 | 403.5±16.2 |
| Feed intake (g/day) | 56.5±4.1$^{ab}$ | 62.4±3.9$^{a}$ | 47.9±2.4$^{b}$ |
| Water consumption (mL/day) | 321.0±42.2$^{a}$ | 315.8±44.5$^{a}$ | 275.8±29.3$^{b}$ |
| Hepatic weight (g) | 14.63±0.55$^{ns}$ | 13.42±0.59 | 13.58±0.59 |
| Pancreatic weight (g) | 0.92±0.07$^{ns}$ | 0.93±0.06 | 0.83±0.04 |

Values with different letters are significantly different at $p<0.05$.
Values are means±SE of six rats per group.
ns: not significant. CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

studies have also been reported that the administration of mushrooms such as *Lentinus edodes, Auricularia auricular-judae* and *Glifola frondosa* or mushroom polysaccharides administrated in the diet and/or drinking water in STZ-diabetic rats and KK-Ay mice were significantly reduced in water consumption, feed intakes and blood glucose compared to the corresponding to their diabetic control rats [16,45,46].

### Blood glucose concentrations

In accordance to the recommendations of the WHO Expert Committee on diabetes mellitus, it is important to investigate the hypoglycemic action from plants which were originally used in traditional medicine[1]. In recent years, there has been interest in the blood glucose-lowering properties of mushrooms, including *Ganoderma lucidum*[49], *Lentinus edodes*[45], *Auricularia auricula* judae[46], and *Grifola frondosa*[24] in STZ- and alloxan-induced diabetic rats, genetically diabetic KK-Ay mice, Zucker diabetic rats, and diabetic patients[23]. Previous studies have also shown that the hypoglycemic components containing these mushrooms include polysaccharide, peptidoglycans, terpenoids, and dietary fiber. Concentrations of crude polysaccharides were 42.9% in chaga mushroom and 39.1% in fermented chaga mushroom (Table 1). Chaga mushroom containing polysaccharides would be an ideal candidate for glycemic control in diabetic animal experiment. Changes in blood glucose level at regular intervals during the experimental period are present in Fig. 1. The blood glucose of the control group gradually increased during the experimental period, but the FCM supplementation in the diet resulted in lower blood glucose from one week after feeding compared with the control group. Chemically, the mushroom polysaccharides of *Garnoderma lucidum* and *Lentinus edodes* having hypoglycemic activities constituted the glycoprotein linked together by beta-glycoside linkages as polysaccharide peptide, of which consist of xylose, rhamnose, fructose, galactose, mannose, and glucose[23,45,49]. Polysaccharides obtained from fruiting body of chaga mushroom constituted xylogalactoglucan[33,43], which composed of mainly xylose and galactose with hypoglycemic effect on diabetic rats[45,48]. Previous studies have indicated that oligosaccharides were also reported with with hypoglycemic effect on diabetic rats[26, 30]. Moreover, oligosaccharides obtained from fermented chaga mushroom showed the significantly cytotoxic effect on cancer cell lines HCT-15 and AGS[8]. These results suggest

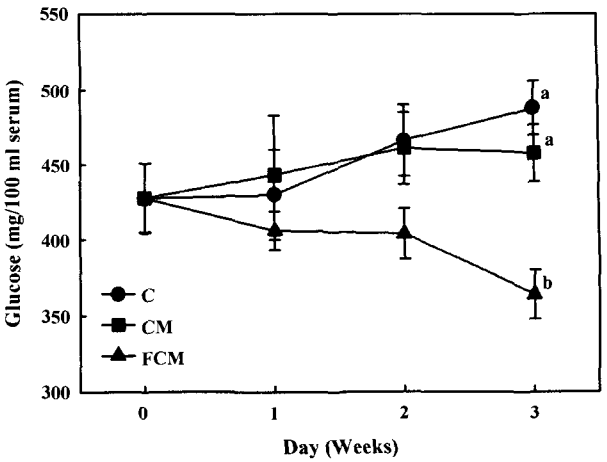


Fig. 1. Changes of concentrations of serum glucose in STZ-induced diabetic rats.
Values with different letters are significantly different at $p<0.05$. (mean±S.E., n=6). C: control diet, CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

that the administration of fermented chaga mushroom containing both polysaccharides and oligosaccharides was more pronounced to reduction in blood glucose concentration of diabetic rats when compared to chaga mushroom.

### Insulin concentration

Concentrations of serum insulin are present in Fig. 2. Insulin concentrations was slightly higher in the FCM group than in the control and CM groups. STZ treatment inhibited

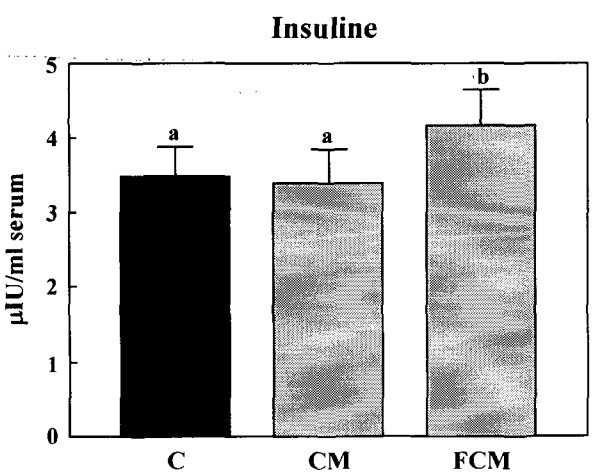


Fig. 2. Concentrations of serum insulin in STZ-induced diabetic rats.
Values with different letters are significantly different at $p<0.05$. (mean±S.E., n=6). C: control diet, CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

insulin secretion from the pancreas through the selectively destruction of β-cells in the pancreatic islets[27]. Inhibited insulin secretion through the β-cells destruction in the pancreatic islets in STZ-diabetic rats has been closely correlated with elevated blood glucose level. Recently, there has been increasing evidence that an aqueous extract of mushroom stimulated the insulin secretion from a BRIN-BDll pancreatic β-cell line and from isolated islet cells of rats fed mycelial Lentinus edodes[16,45].

Zhang et al reported that polysaccharide from fruting bodies of Garnoderma lucidum dose-dependently reduced serum glucose and increased serum insulin levels for 10 days in alloxan-induced diabetic rats[49]. They were also reported that polysaccharide from fruting bodies of Garnoderma lucidum produced the hypoglycemic effect potentially by increasing the plasma insulin level in normal rats and mice[48]. In our preliminary study, an elevated insulin concentration in STZ-induced diabetic rats fed a diet supplemented with fermented mushroom milk product containing mushroom polysaccharides was strongly related to the degree of diabetic control[11]. Thus, these results suggested that the hypoglycemic effect of fermented chaga mushroom in the STZ-diabetic rats may be, at least in part, due to the enhancement of insulin secretion from the pancreas. Consequently, the increase in the blood insulin concentration in diabetes mellitus caused by fermented chaga mushroom may be an important factor in improving the hyperglycemia of STZ-induced diabetic rats.

## AST and ALT activities

It was well known that alanine or aspartate aminotransferases are elevated in some diseases such as diabetes mellitus and infectious hepatities[20,37]. The activities of AST and ALT are generally increased by metabolic changes in the liver by the administration of toxins such as diabetic induced STZ or alloxan, cirrhosis of the liver, hepatities and liver cancer[37]. Thus, these activities can be used as biomarker to monitoring the extent of hepatic injury in diabetic animal models. The activities of AST and ALT were significantly lower in the FCM group than in the control group (Fig. 3). Our previous study also observed that the ALT and AST activities were significantly decreased in type I STZ-diabetic rats and type II Zucker diabetic rats fed diet supplemented with fermented mushroom milk containing mushroom polysaccharides[19]. Yang et al. reported that the AST and ALT activities were significantly reduced under the influence of Lentinus edodes exo-polymer in STZ diabetic rats[45]. Lee et all. reported[19] that the dramatical increase in the serum ALT and AST activities in D-galactosamine-induced hepatic injury rats was significantly decreased by each of the following mushrooms ; *Fulammulina velutipes* by 71.3% and 75.1%, *Lentinus edodes* by 55.5% and 65.2% and *Pleurotus ostreatus* by 28.2% and 51.2%. Thus, present study confirmed the hepatoprotective effect of fermented chaga mushroom on hepatic injury as complication in diabetes mellitus.

## Triglyceride and Cholesterol concentrations

Hyperlipidemia is a major risk factor leading to lifestyle-related diseases, obesity, hypertension, arteriosclerosis, diabetes mellitus, and much attention has focused on improving serum lipid by the intake of an ideal diet[18,19]. The serum

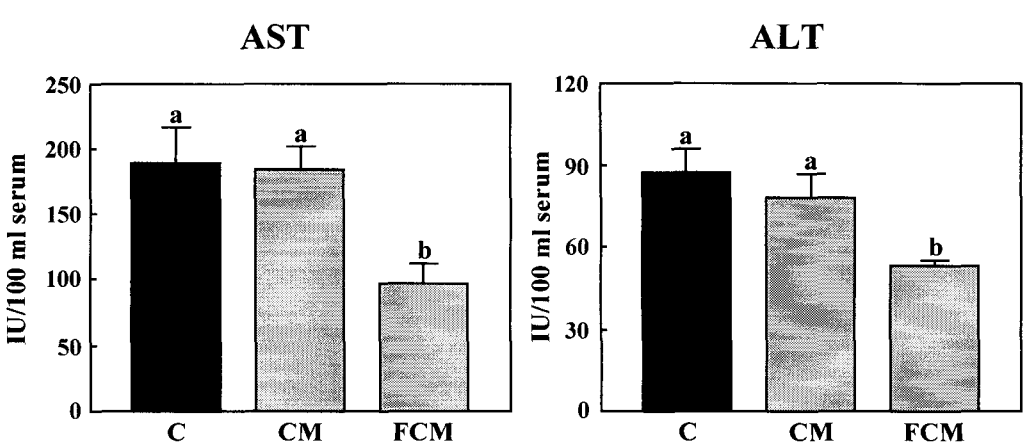


Fig. 3. Activities of serum ALT and AST in STZ-induced diabetic rats.
Values with different letters are significantly different at $p<0.05$. (mean±S.E., n=6). C: control diet, CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

levels of triglyceride and cholesterol were strongly related to the degree of diabetic control in diabetes mellitus[4]. Hypolipidemic effect of edible mushrooms, including *Ganoderma lucidum*[6], *Grifola frondosa*[15,40], *Lentinus edodes*[15], *Flammulina velutipes*[15], and *Volvariella volvacea*[15] have been previously reported to decrease the triglyceride or/and cholesterol of serum in hyperlipidemic and diabetic animal models. In our recently studies, there have been interest in the cholesterol lowering properties of mushroom powder feeding including *G. lucidum*, *P. ostreatus*, *L. edodes*, and *F. velutipes* in the hypercholesterolemic rats[22]. Our previous study also demonstrated the triglyceride-lowering effect of fermented mushroom milk product containing mushroom polysaccharides in STZ-diabetic rats[19]. Serum triglyceride concentrations were significantly decreased in the STZ FCM-fed rats compared to STZ control rats (Fig. 4). The administration of L. edodes exo-polymer (200 mg/kg BW) in STZ-diabetic rats lowered the plasma triglyceride and total cholesterol concentrations by 44.5% and 25.1%, respectively, as compared to STZ control rats[45]. Kim et al. has been demonstrated that the protein-bound polysaccharide from mushroom also lowered the serum triglyceride and glucose concentrations in STZ-diabetic rats[21]. Previous reports found that serum triglyceride concentrations decreased significantly in spontaneously hypertension rats response to the consumption of whole maitake mushroom at the level of 20% administration[40]. Thus, edible mushrooms are an ideal diet for the dietetic prevention of hyperlipidemic due to their ability to lower the serum cholesterol and triglyceride concentrations because of their high contents of dietary fiber, lectins, glucans, glycoprotein, polysaccharide, and physiological components[6].

### Creatinine and BUN

The concentrations of serum creatinine and blood urea nitrogen (BUN) are shown in Fig 5. Serum BUN concentrations were significantly lower in the FCM group than in both the CM and control groups. No significant difference was observed in the serum creatinine concentrations among the experimental groups. Al-Ghaithi *et al.* also reported that the serum BUN concentrations were significantly increased after the onset of STZ-induced diabetes, but were not observed in the serum creatinine concentrations of diabetic rats[2].

### Lipid peroxidation (TBARS)

Lipid peroxide mediated tissue damages has been observed in the development of diabetes mellitus which is caused by selective and progressive destruction of pancreatic beta-cells[27]. Previous studies observed an increase in TBARS in the tissues such as pancreas, liver, kidney, heart, and brain of animals with diabetes induced alloxan and streptozotocin[38]. Present study also observed that TBARS concentrations in hepatic homogenate, microsomal and mitochondrial subcellular were significantly lowered by the administration of FCM in the STZ-diabetic rats (Fig. 6). Increased lipid peroxidation in liver under diabetic conditions can be due to increased oxidative stress in the hepatoma cell, which is associated with abnormalities in the content of antioxidants. Glutathione is knowen to protect the cellular system against the toxic effects of lipid peroxidation[36]. Previous studies have been observed a decrease

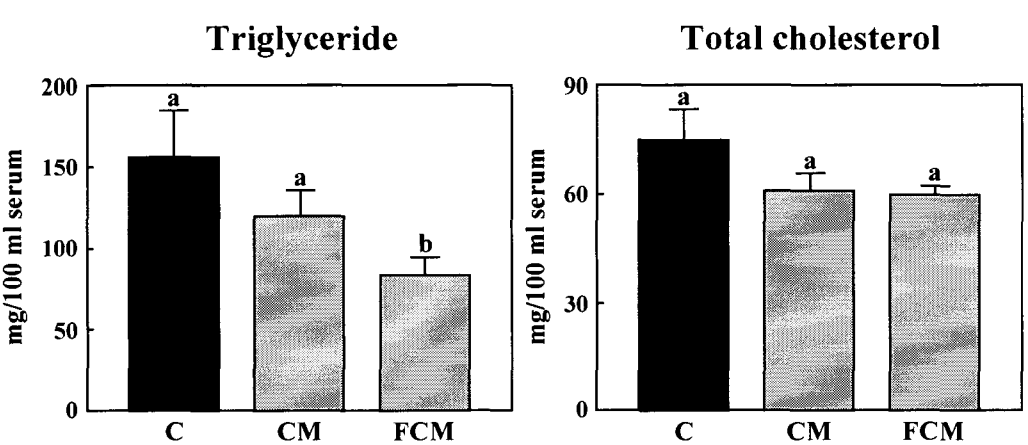


Fig. 4. Concentrations of triglyceride and cholesterol in STZ-induced diabetic rats.
Values with different letters are significantly different at $p<0.05$. (mean±S.E., n=6). C: control diet, CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

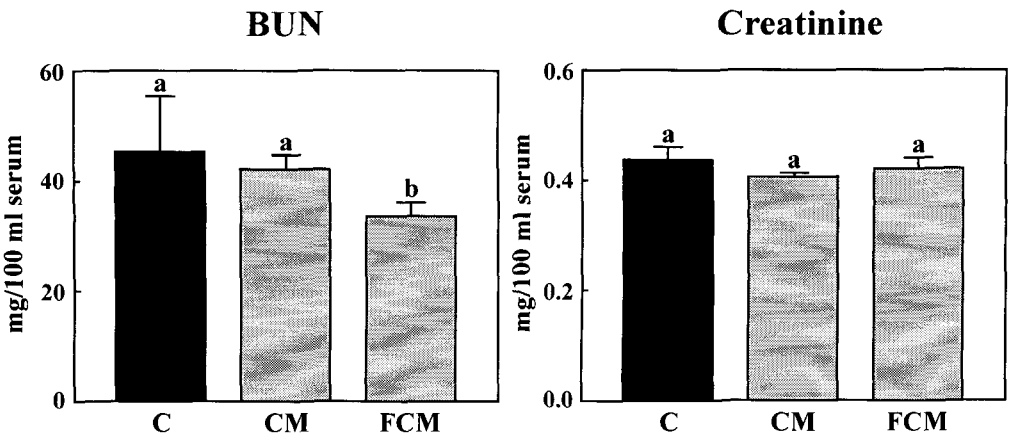


Fig. 5. Concentrations of blood urea nitrogen and creatinine in STZ-induced diabetic rats.
Values with different letters are significantly different at $p<0.05$. (mean±S.E., n=6). C: control diet, CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

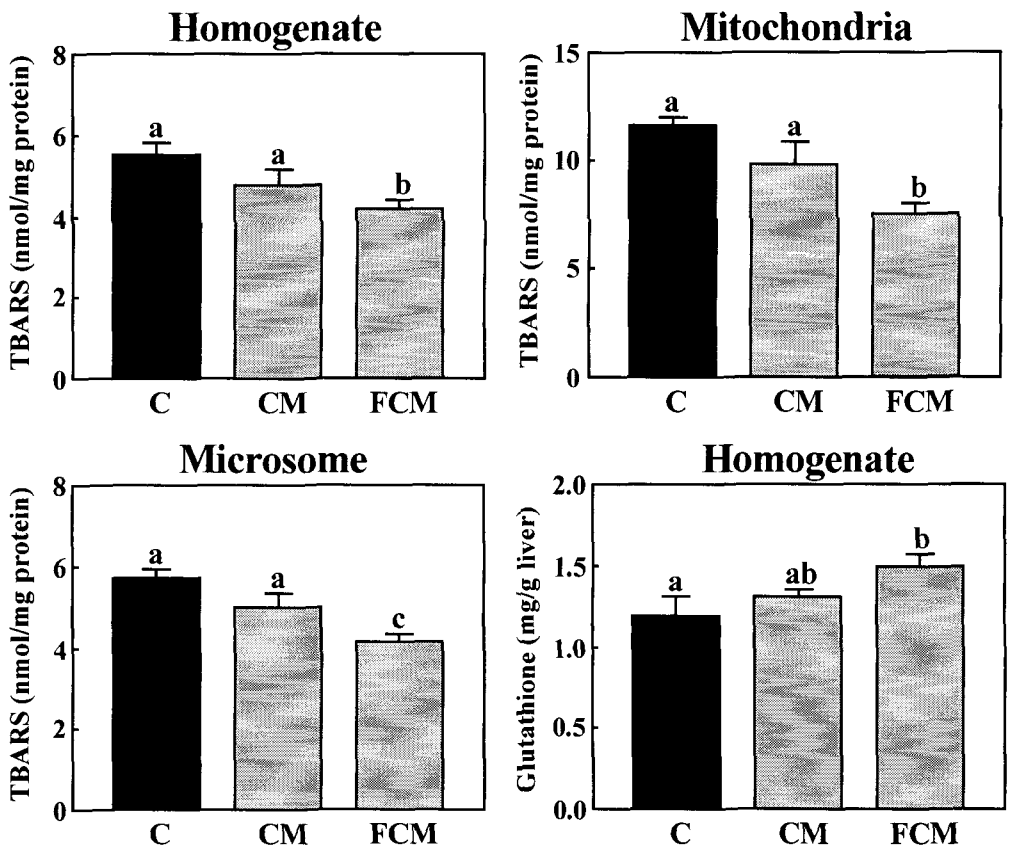


Fig. 6. Concentrations of hepatic TBARS in STZ-induced diabetic rats.
Values with different letters are significantly different at $p<0.05$. (mean±S.E., n=6). C: control diet, CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

in glutathione concentrations in liver, kidney, and heart in STZ- and alloxan-induced diabetic rats[35,38]. The decrease of glutathione levels in these tissues represents increased utilization due to oxidation stress. Alteration in nonenzymic antioxidant is observed in the present study (Fig. 6). Hepatic glutathione concentrations were significantly higher in the FCM group than in the control group, indicating a marked effect of FCM administration on the endogenous antioxidant

system. However, CM treatment showed a moderate antioxidative activity in the STZ-diabetic rats. Accumulation of malondialdehyde as biomarker for lipid peroxidation in mitochondria has been reported in diabetic animal, possibly causing further damage to mitochondrial metabolic systems[41].

Pancreatic beta cells are highly susceptible to cytotoxic agents such as STZ and alloxan, which induce a cascade of cellular events including DNA strand breaks, activation of poly (ADP-ribose) synthase, and NAD depletion, resulting in impaired function and cell death[29,44]. Concentration of pancreatic TBARS in the FCM group was also significantly decreased when the corresponding control group, but tended to decrease in the CM group without statistically significant different (Fig. 7). Zhang *et al.* reported that the pancreatic TBARS concentrations increased during diabetes by alloxan treatment, but this elevation significantly and dose-dependently decreased by administration of mushroom polysaccharide[49]. They also reported that polysaccaride administration from *Ganoderma lucidum* was useful in protecting against alloxan-induced pancreatic islets damage *in vivo* and *in vitro*, because decreased blood glucose and increased blood insulin concentrations[48].

Recently, mushrooms have shown significantly antioxidant activity which is related with phenolics components[5,9,25, 32]. Total phenolics concentrations of chaga mushroom and fermented chaga mushroom were 0.8% and 0.9% (Table 1),

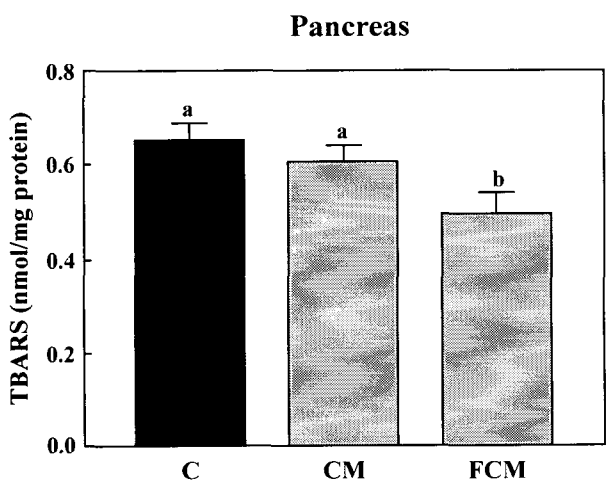


Fig. 7. Concentrations of pancreas TBARS in STZ-induced diabetic rats.
Values with different letters are significantly different at $p<0.05$. (mean±S.E., n=6). C: control diet, CM: chaga mushroom powder diet, FCM: fermented chaga mushroom powder diet.

which was consistent with total phenolics amounts by Lee and Jang by 0.48~1.28%[25], Benoit *et al.* by 1.17~1.38% [5], and Mau *et al.*[32], suggest that total phenols were the major naturally occurring antioxidant components found in mushrooms.

In conclusion, these results suggest that oral administration of fermented chaga mushroom containing polysaccharides and oligosaccharides, and phenolics component may exert hypoglycemic and antioxidative effects due to their components on the STZ-diabetic rats.

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## 초록 : Streptozotocin 유발 당뇨쥐에서 발효 차가버섯의 항당뇨 및 항산화 효과

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차가버섯 (*Inonotus obliquus*) 분말을 *Bacillus* sp.로 발효시켜 streptozotocin (STZ)-유발 당뇨쥐에 5% (w/w) 수준으로 첨가한 반합성 식이를 3주간 투여하여 혈당치 및 과산화지질 농도에 미치는 영향을 검토하였다. 차가버섯 및 발효 차가버섯의 다당체는 각각 42.9% 및 39.1%였으며, 폴리페놀 화합물 함량은 각각 0.80% 및 0.91%였다. 식이 및 음료 섭취량, 혈청 중의 glucose, insulin, triglyceride, blood urea nitrogen 농도는 당뇨 대조군과 차가버섯 투여군 보다는 발효 차가버섯 투여군에서 현저히 감소하였다. 혈청 중의 간 기능 임상지료 효소인 AST 및 ALT 활성도 발효 차가버섯 투여군에서 역시 감소하였다. 그러나 혈청 total cholesterol 및 creatinine 농도는 각 실험군간에 유의적인 차이는 없었다.

한편, 간 조직의 homogenate, microsomal 및 mitochondria 분획의 과산자질 농도는 당뇨쥐에 발효 차가버섯 투여로 현저히 감소하였다. 간 조직에서 내인성 항산화물질로 알려져 있는 glutathione 농도가 발효 차가버섯 투여군에서 현저히 증가함으로써 과산화지질 농도 억제에 의한 항산화 활성과 밀접한 관련성을 가진 것으로 나타났다. 차가버섯 투여군에서는 발효 차가버섯 보다는 미약한 항산화 활성을 보였다. 이상의 결과에서 발효 차가버섯은 streptozotocin-유발 당뇨쥐에서 우수한 항당뇨 및 항산화 효과를 발휘하였다.