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Note

Dietary Effect of *Ganoderma lucidum* Mushroom on Blood Pressure and Lipid Levels in Spontaneously Hypertensive Rats (SHR)

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The fruiting body of the fungus *Ganoderma lucidum* (FR.) KARST (Polyporaceae), called "Reishi" or "Mannentake," has long been used as a folk medicine to treat hepatopathy, chronic hepatitis, nephritis, hypertension, arthritis, neurasthenia, insomnia, bronchitis, asthma, and gastric ulcer in China and Japan (*1*). It is said that some of its physiological effects are distinct depending upon the strain used and the nature of cultivation (*2–4*).

We have previously reported the preventive effect of dietary shiitake and maitake mushrooms on the increase of blood pressure in SHRs (*5*). In the present study, the effect of a powder prepared from *Ganoderma lucidum* mushroom on the blood pressure and lipid levels of spontaneously hypertensive rats (SHR) were examined.

The powder of the fruiting bodies (ordinary mushroom form) of the strain of *Ganoderma lucidum*, which were cultivated in Nagano prefecture, Japan and are designated as "Nagano" were kindly provided by Asahi Chemical Industry Co., Ltd., Tokyo, Japan.

Preparation of *Ganoderma lucidum* powder: "Nagano" strain of the mycelium of *Ganoderma lucidum*, which was isolated from the cultured fruiting body was inoculated into a liquid medium containing 3% D-glucose, 2% soybean powder, 1% sweet potato powder, 0.1% KH_2PO_4, and 0.1%$MgSO_4 \cdot 7H_2O$, and grown at 32°C by shaking culture for 4 days. After 4 days, the mycelium overgrowing medium was

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Table 1. Composition of *Ganoderma lucidum* powder.

Ingredients		Value per 100 g
Proteins[a]		42.2 g
Lipids[b]		0.9 g
Carbohydrates	Fiber[c]	0.4 g
	Non-fibrous carbohydrates[d]	50.4 g
Water		1.3 g
Ash		4.8 g
Calcium		752 mg
Iron		21.7 mg
Vitamin A		200 I.U.
Vitamin B_1		0.45 mg
Vitamin B_2		7.35 mg
Vitamin C		2.1 mg
Vitamin D		160 I.U.
Lysine		220 mg
β-D-glucan[e]		442 mg
Soybean saponin[e]		530 mg
Ergosterol[f]		39.9 mg

[a] Kjeldahl method, [b] A.O.A.C. method, [c] Henneberg and Stohmann method, [d] 100 minus other ingredients, [e] GLC, [f] HPLC.

raked out and mixed into a jar containing the aforementioned liquid medium. The culture medium was fermented at 32°C (aeration: 40 liter/min, 200 rpm) for 4 days. The broth was sterilized, freeze-dried and powdered (yield: 36.0 g from 1 liter of medium). The composition of the *Ganoderma lucidum* powder is shown in Table 1.

Fourteen 4-week-old male albino SHRs (from Funabashi Farm) of the Okamoto strain (*6*) weighing about 76 g were divided into two dietary groups of 7 animals each. The animals were fed a basal diet consisting of 10% egg protein (control) and a basal diet with addition of 5% *Ganoderma lucidum* mushroom powders. The composition of the diets are as published previously (*5*) except that the type of mushroom is different. The rats were given the diets and drinking water supplemented with 0.5% NaCl *ad libitum* for 4 weeks. The rats were kept under controlled experimental condition and blood pressure was recorded as previously described (*5*). Most measurements were carried out in the afternoon to minimize the effects of circadian variation (*7*). The heart rates were also measured at this time. Daily food intake and body weight were measured.

At the end of the 4-week feeding period, the animals were starved overnight and then killed by ether anesthetization to obtain liver and blood from abdominal aorta. Plasma total and free cholesterol, triglyceride and phospholipid levels were measured by using assay kits (Wako Pure Chemical Industries, Ltd., Osaka). For determination of free cholesterol in rat liver, 5α-cholestane (Sigma Chemical Co.)

was added as an internal standard to liver homogenates and extracted by chloroform–methanol (2 : 1,v/v) according to the procedure of Folch *et al.* (*8*). The chloroform extracts were evaporated to dryness and the amount of free cholesterol in the liver homogenate was determined by gas-liquid chromatography (GLC) as previously described (*9*, *10*). For determination of total cholesterol in rat liver, the chloroform extracts were hydrolyzed with 10% ethanolic-NaOH at 90°C for 90 min, and evaporated to dryness. Then the total cholesterol was extracted with *n*-hexane and determined by GLC as described by Komai and Kimura (*10*). Liver triglyceride was determined by the procedure of Soloni (*11*) and liver phospholipid with an assay kit (Wako Pure Chemical Industries, Ltd., Osaka) following the extraction procedure of Folch *et al.*(*8*).

Student's *t*-test was used for the statistical analysis of the data.

Body weight gain, liver weight, and food intake are shown in Table 2. No significant difference was observed between the two groups. After the 4-week feeding period, the systolic blood pressure of rats fed *Ganoderma lucidum* was significantly lower ($p<0.05$) than that of the control (Fig. 1). This result indicates that the powder of the Nagano strain of the fruiting body of *Ganoderma lucidum*

Table 2. Effect of *Ganoderma lucidum* on body weight gain, liver weight, and food intake of SHRs.

Diets	Body wt gain (g/4 weeks)	Liver wt (g)	Food intake (g/4 weeks)	Food efficiency
Control	150±3	7.1±0.3	682±11	0.22
Ganoderma lucidum	135±6	7.2±0.4	671±27	0.20

Each value represents the mean±SE for 7 rats.

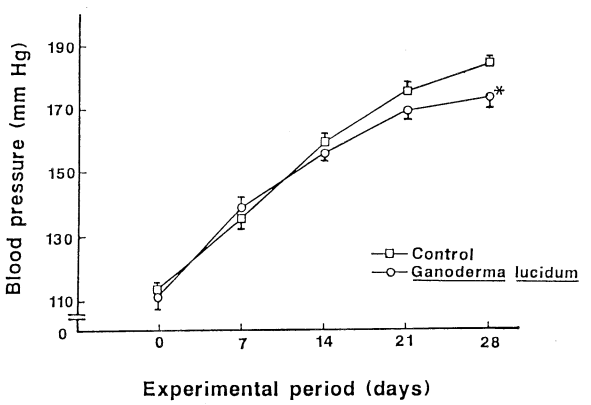

Fig. 1. Changes in systolic blood pressure levels of spontaneously hypertensive rats fed *Ganoderma lucidum* diet. Each point represents the mean±SE for 7 rats. Significantly different from control, $*p<0.05$.

Table 3. Effect of *Ganoderma lucidum* on plasma and liver cholesterol, triglyceride and phospholipid levels in SHRs.

Diets	Plasma (mg/100 ml)				
	Cholesterol			TG	PL
	Total	Free	Ester ratio (%)		
Control	62.9±2.1	16.0±1.3	74.5	50.7±2.1	93.5+8.7
Ganoderma lucidum	49.9±2.2*	15.6±1.9	68.7	54.7±5.2	85.4±5.8

Table 3. (continued)

Diets	Liver lipid (mg/g wet)				
	Cholesterol			TG	PL
	Total	Free	Ester ratio (%)		
Control	5.2±0.7	1.7±0.1	67.4	27.2±1.9	17.4±0.4
Ganoderma lucidum	2.3±0.5*	1.7±0.2	26.1**	14.7±2.0*	15.9±0.8

Each value represents the mean±SE for 7 rats. Significantly different from control, $*p<0.01$, $**p<0.001$. TG, triglyceride; PL, phospholipid.

may have some active substance which suppresses the elevation of blood pressure. There was no significant difference in heart rate between the two groups. It was 392±14 and 412±11 beats/min, respectively.

The plasma and liver cholesterol, triglyceride and phospholipid levels are shown in Table 3. The plasma total cholesterol level in SHRs fed *Ganoderma lucidum* was significantly lower ($p<0.01$) than that of the control, whereas no significant difference in plasma free cholesterol, triglyceride and phospholipid levels was observed between the two groups. The total liver cholesterol and triglyceride levels were significantly lower ($p<0.01$) in *Ganoderma lucidum* fed rats when compared with the control. There was almost no difference in liver free cholesterol level between the two groups. Therefore, the percentage of cholesterol ester was significantly lower ($p<0.001$) in *Ganoderma lucidum*-fed animals. The liver phospholipid levels were not significantly different between the experimental groups.

The low plasma cholesterol levels in the SHRs in our experiment was in agreement with previous reports (*12, 13*). However, the present study showed that the level of plasma cholesterol was significantly lowered in SHRs fed *Ganoderma lucidum* as compared with controls. The authors (*5*) and others (*14*) have previously

reported the plasma cholesterol lowering effects of some other mushrooms in experimental rats. The decrease in cholesterol concentration was not limited to the plasma but also present in the liver after *Ganoderma lucidum* feeding (Table 3). It has been reported that the liver cholesterol levels in SHRs were significantly higher than that of the corresponding normotensive rats (*15*). The high cholesterol level in the livers of our control SHRs was in agreement with that report. The consistent relationship between plasma and liver cholesterol levels suggests that the alterations in plasma cholesterol level is not entirely ascribable to the transportation of cholesterol between the liver and the plasma under our experimental conditions. A low plasma and liver cholesterol level in *Ganoderma lucidum*-fed animals may be due to the inhibition in cholesterol synthesis and/or acceleration of cholesterol metabolism.

Although the exact mechanism for these effects was not known, our results suggest that an appropriate dietary manipulation may prevent the increase of blood pressure and reduce plasma and liver cholesterol levels in SHRs.

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