Differing Effects of Water-Soluble and Fat-Soluble Extracts from Japanese Radish (Raphanus sativus) Sprouts on Carbohydrate and Lipid Metabolism in Normal and Streptozotocin-Induced Diabetic Rats

Hironobu Taniguchi¹, Rieko Muroi², Kazuo Kobayashi-Hattori²*, Yasushi Uda³, Yuichi Oishi² and Toshichika Takita²

¹Department of Nutrition, Food Science and Culinary Arts, Toita Women's College, 2–21–17 Shiba, Minato-ku, Tokyo 105-0014, Japan
²Department of Nutritional Science, Faculty of Applied Bio-Science, Tokyo University of Agriculture, 1–1–1 Sakuragaoka, Setagaya-ku, Tokyo 156–8502, Japan
³Department of Bioproductive Sciences, Faculty of Agriculture, Utsunomiya University, 350 Minemachi, Utsunomiya, Tochigi 321–8505, Japan

(Received October 10, 2006)

Summary We have shown previously that Japanese radish (Raphanus sativus) sprouts (JRS) improve blood glucose levels in diabetic rats. In this study, we investigated the components in JRS that caused this hypoglycemic effect, by examining the effects of water-soluble (WSE) and fat-soluble (FSE) extracts of JRS on diabetes markers in normal (NM) and streptozotocin (STZ)-induced diabetic (DM) rats. The NM and DM rats were divided into a control group and 2 test groups (WSE (2.2%) or FSE (0.2%)), with the rats (n=6/group) then being maintained for 3 wk on either a control diet or one of the test diets; this was followed by the measurement of serum concentrations of glucose, insulin, glycoalbumin, fructosamine, ketone bodies, and lipids (cholesterol and triglyceride) and liver concentrations of lipids (total lipid, total cholesterol, and triglyceride). The FSE suppressed insulin secretion and improved lipid metabolism in the NM rats. The effect of WSE was different from that of the FSE as it decreased blood glucose levels without increasing insulin secretion and also lowered glycoalbumin and fructosamine levels in the DM rats. Therefore, the WSE have potential as functional food components with the hypoglycemic effect.

Key Words Japanese radish sprouts, water-soluble extract, fat-soluble extract, diabetes mellitus, streptozotocin

Diabetes mellitus is a heterogeneous metabolic disorder manifesting as hyperglycemia and other symptoms and is becoming an increasing health problem worldwide. In Japan, it is estimated that more than 12 million people are hyperglycemic (1). The basic treatments for diabetes are dietary and exercise therapies with drug administration being necessitated by the severity of the diabetic symptoms. For advanced diabetes, there are two methods of treatment—administration of insulin or drugs that promote insulin secretion and reducing the increase in blood glucose by inhibiting the digestion and absorption of ingested carbohydrates. In the latter treatment option, food materials with specific health benefits, such as resistant starch, have been investigated (2–4).

The effects of Lagerstroemia speciosa, which has been used as a folk remedy for diabetes, have been known for a long time (5, 6). Recently similar effects have been reported for other natural products including Momordica charantia and Ginseng radix (7–12). There are 400 natural products, including these materials, which have been used as folk remedies (13). However, despite many reports on the beneficial effects of natural products on diabetes mellitus, no information is available about the anti-diabetic activity of Japanese radish (Raphanus sativus) sprouts (JRS). Thus, we previously investigated the effects of dried powder of JRS on glucose and lipid metabolism in streptozotocin (STZ)-induced diabetic rats and normal rats and showed that a diet containing 5% dry powder of JRS produced significant decreases in the blood glucose level, indicating that the powder may be useful for improving diabetes (14).

This study was an extension of this previous work and investigated the diabetes-improving component of JRS by examining the effects of water- and fat-soluble extracts of JRS on markers of diabetes in normal and STZ-induced diabetic rats.

MATERIALS AND METHODS

Sample preparation. Commercial JRS (12 kg) were boiled for 3 min, mashed, extracted with 70% methanol (JRS : 70% methanol = 3 : 7 (w/v)) in a dark place over-
night, and then filtered. In addition, the residue was extracted with 70% methanol for 3 h and filtered. These filtrates were combined, and the methanol in the filtrate was removed using a rotary evaporator. Diethyl ether was added to the residue (Diethyl ether : residue = 1 : 1 (w/v)), followed by separation of the water- and fat-soluble phases with a separatory funnel. The two fractions (water-soluble extract (WSE) and fat-soluble extract (FSE)) were lyophilized and powdered for use as the test samples. The recovery of the WSE and FSE was 373.68 ± 1.23% and 32.35 ± 0.64%, respectively.

Animals and experiment groups. Male Wistar rats (8 wk; CLEA Japan, Inc., Tokyo, Japan) were maintained in six apartment-type connected cages under the conditions of a 12-h lighting cycle, 22±2˚C room temperature, and 50±10% humidity. In this study, each administration of the WSE and FSE was treated as a separate experiment. After acclimatization with an AIN-76 standard diet (Table 1) for 3 d, one-half of the rats received an intraperitoneal injection of STZ (40 mg/kg body weight) dissolved in 10 mM citrate buffer (pH 4.4) in order to induce diabetes. All sucrose in the diet was replaced with cornstarch after the STZ administration in order to suppress the increase in the postprandial blood glucose level (Table 1). After a further 10 d, the normal (NM) and diabetic (DM) rats were divided into a blood glucose level (Table 1). After a further 10 d, the normal (NM) and diabetic (DM) rats were divided into a diet after STZ injection. The animal experiments in the present study were performed according to the guidelines for the care and use of experimental animals established by the ethics committee of Tokyo University of Agriculture.

Analytical methods. Serum levels of total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), triglyceride (TG), fructosamine, glucose, and ketone bodies were measured using an automatic analyzer and specific diagnostic kits. Serum concentrations of insulin and glycoalbumin were determined using a rat insulin enzyme-linked immunosorbent assay (ELISA) kit (Shibayagi, Gunma, Japan) and the Glycabumin ELISA kit (Exocell Inc., Philadelphia, PA, USA), respectively.

For the extraction of hepatic lipids (16), the largest lobe of the liver (1 g) was homogenized in a mixture of chloroform-methanol (2 : 1) using a polytron and then placed in a dark place overnight. After filtration of the suspension, the filtrate was stored at −20˚C until use as an extract in the following assays. The concentrations of total lipid (TL), TC, and TG in the extract were measured using conventional gravimetric analysis, the Zak-Henly method (17, 18), and the Triglyceride G Test Wako kit (Wako Pure Chemical Industries, Ltd., Osaka, Japan), respectively.

Statistical analyses. The results were expressed as the mean±standard error (SE). Statistical analysis was performed using SPSS (ver. 9.0) software. The statistical significance of the difference between the means of the groups was assessed by Student’s t-test.

RESULTS

Changes in diabetes markers in NM and DM rats treated with the WSE and FSE

Figure 1 shows the body weight change and food intake of the NM and DM rats fed the WSE and FSE. In the NM and DM rats, on the whole, few differences were observed between the control diet and test diet treatment groups although some significant differences were observed during the experiments. Table 2 shows the serum levels of glucose, insulin, glycoalbumin, fructosamine, and ketone bodies in the NM and DM rats treated with the WSE and FSE. There was no significant difference in glucose levels between the CO and WSE treatment groups in the NM rats. In contrast, glucose levels decreased by approximately 32% in the WSE-treated DM rat group compared to the CO. In the FSE

Table 1. Composition of diets.

| Ingredients          | WSE administration test | FSE administration test |
|----------------------|-------------------------|-------------------------|
|                      | Acclimatization diet    | Diet after STZ injection | Control diet | WSE diet | Acclimatization diet | Diet after STZ injection | Control diet | FSE diet |
| Casein               | 20.0                    | 20.0                    | 20.0         | 20.0     | 20.0                   | 20.0                    | 20.0         | 20.0     |
| Sucrose              | 50.0                    | 50.0                    |              |          |                        |                        |              |          |
| Corn starch          | 15.0                    | 65.0                    | 65.0         | 62.8     | 15.0                   | 65.0                    | 65.0         | 64.8     |
| Mineral mix          | 3.5                     | 3.5                     | 3.5          | 3.5      | 3.5                    | 3.5                     | 3.5          | 3.5      |
| Vitamin mix          | 1.0                     | 1.0                     | 1.0          | 1.0      | 1.0                    | 1.0                     | 1.0          | 1.0      |
| dl-Methionine        | 0.3                     | 0.3                     | 0.3          | 0.3      | 0.3                    | 0.3                     | 0.3          | 0.3      |
| Choline bitartrate   | 0.2                     | 0.2                     | 0.2          | 0.2      | 0.2                    | 0.2                     | 0.2          | 0.2      |
| Cellulose powder     | 5.0                     | 5.0                     | 5.0          | 5.0      | 5.0                    | 5.0                     | 5.0          | 5.0      |
| Corn oil             | 5.0                     | 5.0                     | 5.0          | 5.0      | 5.0                    | 5.0                     | 5.0          | 5.0      |
| Water-soluble extract (WSE) |                   | 2.2                     |              |          |                        |                        |              |          |
| Fat-soluble extract (FSE) |                    |                        |              |          |                        |                        |              | 0.2      |

Notes: Based on AIN-76.

1 Weight percent.
2 Analytical methods. Serum levels of total cholesterol (TC), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), triglyceride (TG), fructosamine, glucose, and ketone bodies were measured using an automatic analyzer and specific diagnostic kits. Serum concentrations of insulin and glycoalbumin were determined using a rat insulin enzyme-linked immunosorbent assay (ELISA) kit (Shibayagi, Gunma, Japan) and the Glycabumin ELISA kit (Exocell Inc., Philadelphia, PA, USA), respectively.

For the extraction of hepatic lipids (16), the largest lobe of the liver (1 g) was homogenized in a mixture of chloroform-methanol (2 : 1) using a polytron and then placed in a dark place overnight. After filtration of the suspension, the filtrate was stored at −20˚C until use as an extract in the following assays. The concentrations of total lipid (TL), TC, and TG in the extract were measured using conventional gravimetric analysis, the Zak-Henly method (17, 18), and the Triglyceride G Test Wako kit (Wako Pure Chemical Industries, Ltd., Osaka, Japan), respectively.

Statistical analyses. The results were expressed as the mean±standard error (SE). Statistical analysis was performed using SPSS (ver. 9.0) software. The statistical significance of the difference between the means of the groups was assessed by Student’s t-test.
Effect of Extracts from Japanese Radish Sprouts on Diabetes

263
treatment groups, no significant difference was noted between the NM and DM rats. Insulin levels were not significantly different between the CO and WSE treatment groups in either the NM or DM rats but were decreased in the FSE-treated NM rat group. Neither extract increased the insulin levels in any of the groups. Glycoalbumin levels decreased by approximately 43% in the WSE-treated DM rats compared to the CO and by about 24% in the FSE-treated NM rats compared to the CO. Fructosamine levels were decreased by approximately 7% in the DM rats treated with the WSE compared to the CO. In contrast, no significant change was noted following the FSE treatment in either the DM or NM rats. The level of ketone bodies was decreased by approximately 36% in the NM rats treated with the WSE compared to the CO, whereas no significant change was noted after the FSE treatment in either the DM or NM rats.

Changes in serum and hepatic lipid levels in DM and NM rats treated with the WSE and FSE

Table 3 shows the serum and hepatic lipid levels in the NM and DM rats following treatment with either extract. The serum levels of TC, LDL-C, HDL-C, and TG levels in the NM and DM rats treated with the WSE were not significantly different from those in the CO. In the NM and DM rats treated with the FSE, the serum levels of TC, LDL-C, and TG were not significantly different from those in the CO, while the serum level of HDL-C

Table 2. Effect of each extract from Japanese radish sprouts on serum parameters in normal and STZ-diabetic rats.

|                     | Glucose (mg/dL) | Insulin (pg/mL) | Glycoalbumin (%) | Fructosamine (μmol/L) | Ketone body (μmol/L) |
|---------------------|----------------|----------------|------------------|-----------------------|----------------------|
| Normal rats         |                |                |                  |                       |                      |
| Control group       | 196±6          | 3.190±717      | 2.4±0.1          | 190±1                 | 859±90               |
| Water-soluble extract group | 191±11        | 2.273±480      | 2.0±0.1          | 189±1                 | 546±45               |
| Diabetic rats       |                |                |                  |                       |                      |
| Control group       | 670±76         | 352±29         | 3.0±0.2          | 346±4                 | 311±25               |
| Water-soluble extract group | 453±11        | 360±82         | 1.7±0.2          | 323±9                 | 359±42               |
| Normal rats         |                |                |                  |                       |                      |
| Control group       | 167±4          | 4.535±327      | 7.1±0.3          | 189±2                 | 669±75               |
| Fat-soluble extract group | 170±3         | 3.564±225      | 5.4±0.4          | 184±1                 | 558±34               |
| Diabetic rats       |                |                |                  |                       |                      |
| Control group       | 651±21         | 1.597±88       | 8.5±0.5          | 324±5                 | 402±46               |
| Fat-soluble extract group | 625±18        | 1.504±254      | 9.6±0.6          | 320±3                 | 428±69               |

Results are expressed as the mean±SE (n=6/group). Means not sharing a common letter are significantly different (p<0.05).
increased by approximately 18% in the NM rats compared to the CO. With regard to hepatic lipids, the TL, TC, and TG levels were decreased significantly in the DM rats treated with the WSE. However, no change was noted in the levels of TL, TC, or TG in the WSE-treated NM rats. In the NM rats treated with the FSE, the levels of TL and TC were significantly decreased, although no significant change was noted in the TG levels. In the DM rats treated with the FSE, no significant changes were noted in the TL, TC, or TG levels.

### DISCUSSION

In order to improve diabetes control, it is necessary to correct abnormal glucose and lipid metabolism, insulin secretion, and insulin resistance (19–21). To achieve this goal, it is necessary to prioritize the control of blood glucose levels. In this study, the WSE produced significant decreases in blood glucose levels in the DM rats despite no significant difference being observed in the serum insulin levels between the CO and treatment groups. In an experiment in which STZ-induced diabetic rats were treated with white-skinned sweet potatoes (22) or a water extract of *Atractylodis rhizoma* (23), blood glucose levels decreased in association with an increase in blood insulin levels. This finding indicated that the enhanced insulin secretion decreased the blood glucose levels. However, in our study, the WSE decreased blood glucose levels without increasing insulin levels, suggesting the presence of an insulin-like component or an α-glucosidase-inhibiting component in the WSE. With regard to insulin-like components, polyphenolic substances in culinary and medicinal plant aqueous extracts have been reported to have insulin-like activity in vitro (24). It is likely that such substances are responsible for the hypoglycemic effect of the WSE. With regard to α-glucosidase-inhibiting components, our preliminary in vitro experiment showed that the WSE inhibited the activity of sucrase from the rat small intestine (IC$_{50}$ = approximately 6 mg/mL) (data not shown). However, the hypoglycemic effect was observed in only the WSE-administered diabetic group. If the hypoglycemic effect is attributed to an α-glucosidase-inhibiting component, the blood glucose level is decreased in the WSE-administered normal group. Therefore, it is possible that the insulin-like component in the WSE is one of the factors responsible for the hypoglycemic effect. Since the secretion of insulin is insufficient in the DM rats, an insulin-like component in the WSE may exert a pronounced positive influence on the levels of blood glucose, whereas the effect of an insulin-like component in the WSE may be negligible in the NM rats due to a sufficient secretion of insulin. The levels of serum glycated proteins (fructosamine and glycoalbumin) were also significantly decreased in the DM rats treated with the WSE. This indicated that the WSE may lead to improved diabetes control and prevention of complications and in particular, have an important role in inhibiting the progression of atherosclerosis in diabetic patients. In addition, the WSE improved hepatic lipid levels not in the NM rats but in the DM rats. Since insulin affects hepatic lipid levels, an insulin-like component in the WSE may improve the hepatic lipid levels in the DM rats. The level of ketone bodies did not change significantly in the WSE-treated DM rats, but decreased significantly in the WSE-treated NM rats. This finding implied that the WSE might inhibit hepatic fatty acid oxidation or increase the utilization of fatty acids as an energy source in the skeletal and cardiac muscles and the kidney in the NM rats.

In the FSE treatment groups, no significant differences from the CO were noted in either the blood glucose or insulin levels in the DM rats. In the NM rats, no significant difference was noted in the blood glucose levels between the CO and FSE-treated rats, despite the fact that the FSE produced significant decreases in the insulin level. On the basis of these findings, it appears that the FSE may improve insulin sensitivity and therefore be useful in the primary prevention of diabetes. The

---

**Table 3. Effect of water-soluble and fat-soluble extracts on serum and hepatic lipids in normal and diabetic rats.**

|                    | Serum lipids | Hepatic lipids |
|--------------------|--------------|---------------|
|                    | Total choles-| LDL-cholesterol| HDL-cholesterol| Triglyceride | Total lipid | Total choles-| Triglyceride |
|                    | terol (mg/dL)| (mg/dL)       | (mg/dL)       | (mg/dL)     | (mg/g)      | terol (mg/g)| (mg/g)       |
| Normal rats        |              |               |               |             |             |              |              |
| Control group      | 99 ± 3       | 5.57 ± 0.37   | 59.9 ± 1.2    | 185 ± 11    | 123.9 ± 2.6 | 4.74 ± 0.07 | 13.1 ± 0.5   |
| Water-soluble extract group | 103.2 ± 8    | 5.50 ± 0.18   | 62.1 ± 1.0    | 213 ± 24    | 124.1 ± 3.8 | 4.51 ± 0.11 | 14.6 ± 1.0   |
| Diabetic rats      |              |               |               |             |             |              |              |
| Control group      | 119 ± 5      | 3.67 ± 0.18   | 81.2 ± 3.0    | 159 ± 12    | 104.0 ± 3.2 | 4.46 ± 0.05 | 5.4 ± 0.2    |
| Water-soluble extract group | 120 ± 6      | 3.50 ± 0.36   | 86.3 ± 4.7    | 160 ± 16    | 92.7 ± 0.7  | 4.19 ± 0.03 | 4.1 ± 0.2    |
| Normal rats        |              |               |               |             |             |              |              |
| Control group      | 85.8 ± 3.6   | 5.33 ± 0.18   | 53.6 ± 1.9    | 217 ± 28    | 89.9 ± 5.2  | 4.17 ± 0.12 | 18.4 ± 1.2   |
| Fat-soluble extract group | 95.7 ± 4.3   | 5.20 ± 0.14   | 63.0 ± 2.8    | 218 ± 16    | 63.9 ± 6.3  | 3.69 ± 0.12 | 17.4 ± 1.0   |
| Diabetic rats      |              |               |               |             |             |              |              |
| Control group      | 103.5 ± 4.5  | 3.86 ± 0.34   | 74.3 ± 3.0    | 129 ± 14    | 78.0 ± 4.0  | 3.98 ± 0.11 | 7.8 ± 0.7    |
| Fat-soluble extract group | 106.7 ± 4.2  | 4.00 ± 0.00   | 80.8 ± 3.2    | 181 ± 27    | 87.8 ± 8.1  | 4.03 ± 0.14 | 9.8 ± 0.7    |

Results are expressed as the mean ± SE (*n*=6/group). Means not sharing a common letter are significantly different (*p*<0.05).
FSE was associated with significant decreases in glycoalbumin levels in the NM rats, suggesting that this extract may inhibit the progression of arteriosclerosis in healthy individuals. As the level of ketone bodies did not change significantly following the FSE administration in either the NM or DM rats, this suggests that this extract did not affect fatty acid oxidation in the liver. The FSE also improved the level of total lipid and total cholesterol in the livers of the NM rats but not of the DM rats. The FSE contains the green pigment chlorophyll. Since chlorophyll has been reported to improve lipid metabolism (25), the green pigment in the FSE may decrease the hepatic lipid levels in the NM rats, whereas the decreasing effect of the FSE may not be observed in the DM rats because of an abnormal lipid metabolism produced by a low insulin level.

In many cases, diabetes is accompanied by hypertriglyceridemia due to the catabolism of triglycerides in reserve fatty tissues as a result of insulin deficiency; this leads to increased fatty acid production. Since energy is produced from fatty acids in diabetes, the concentration of free fatty acids in the blood increases, with the liver synthesizing triglycerides from these free fatty acids (26). In type 1 diabetes, lipoprotein lipase activity is inhibited, and the lipolysis and catabolism of blood lipids are impaired. The resulting increased levels of total lipid and triglycerides in the liver induce hyperlipidemia and arteriosclerosis. Unlike healthy individuals, hypertriglyceridemia is an important factor in arteriosclerotic vascular diseases in diabetic patients and is considered to be associated with abnormal very low-density lipoprotein (VLDL) composition and delayed metabolism of chylomcron remnants (27, 28). As the WSE inhibited an increase in the liver triglyceride concentration in the DM rats, this extract is expected to improve lipid metabolism in diabetes and prevent complications such as hyperlipidemia and arteriosclerosis. In contrast, the FSE increased the levels of HDL cholesterol. This anti-arteriosclerotic lipid fraction contains lecithin-cholesterol transferase and converts the free cholesterol from peripheral tissues and lipoproteins to a cholesterol ester. HDL-cholesterol is finally incorporated into the liver and catabolized. Therefore, an increase in HDL-cholesterol levels is considered to prevent cholesterol-induced arteriosclerosis (29). Epidemiological studies have reported an inverse correlation between HDL cholesterol and arteriosclerotic diseases (30), with increased HDL levels being shown to prevent arteriosclerotic diseases (31, 32). As serum HDL cholesterol levels increased after treatment with the FSE in the NM rats, this extract is expected to have an anti-arteriosclerotic effect.

In conclusion, this study demonstrated that the WSE of JRS not only decreased blood glucose and glycated protein levels in the DM rats but also improved hepatic lipid metabolism. The FSE was also shown to improve lipid metabolism in the NM rats. In particular, the WSE have potential as functional food components with the hypoglycemic effect. Further studies on the identification of the active components in the WSE are currently in progress.

REFERENCES

1) Kawamori R. 2002. Diabetes trends in Japan. Diabetes Metab Res Rev 18: 89–813.
2) Raben A, Tagliabue A, Christensen NJ, Madsen J, Holst JJ. 1994. Resistant starch: the effect on post-prandial glycemia, hormonal response, and satiety. Am J Clin Nutr 60: 544–551.
3) Gronfeldt Y, Drews A, Bjorck I. 1995. Arepas made from high amylose corn flour produce favorably low glucose and insulin responses in healthy humans. J Nutr 125: 459–465.
4) Reader DM, O’Connell RS, Johnson ML, Franz M. 2002. Glycemic and insulimemic response of subjects with type 2 diabetes after consumption of three energy bars. J Am Diet Assoc 102: 1139–1142.
5) Garcia F, Melencio-Maglalang P. 1957. Application of banabins (a plantulis preparation) and S.B. menus to diabetics. J Philipp Med Assoc 33: 7–15.
6) Kakuda T, Sakane I, Takihara T, Ozaki Y, Takeuchi H, Kuraynaagi M. 1996. Hypoglycemic effect of extracts from Lagerstroemia speciosa L. leaves in genetically diabetic KK-AY mice. Biosci Biotechnol Biochem 60: 204–208.
7) Harada H, Makino F, Iizuka H, Takita T. 2002. Inhibition of glycation by Momordica charantia L. and its influence on lipid metabolizing enzymes in streptozotocin-induced diabetic rats. ITE Lett Better New Technol Med 3: 727–731.
8) Grover JK, Yadav SP. 2004. Pharmacological actions and potential uses of Momordica charantia: a review. J Ethnopharmacol 93: 123–132.
9) Kimura M, Waki I, Chujo T, Kikuchi T, Hiyama C, Yamazaki K, Tanaka O. 1981. Effects of hypoglycemic components in ginseng radix on blood insulin level in alloxan diabetic mice and on insulin release from perfused rat pancreas. J Pharmacobiodyn 4: 410–417.
10) Grover JK, Yadav S, Vats V. 2002. Medicinal plants of India with anti-diabetic potential. J Ethnopharmacol 81: 81–100.
11) Shapiro K, Gong WC. 2002. Natural products used for diabetes. J Am Pharm Assoc 42: 217–226.
12) Yeh GV, Eisenberg DM, Kapchuk TJ, Phillips RS. 2003. Systematic review of herbs and dietary supplements for glycemic control in diabetes. Diabetes Care 26: 1277–1294.
13) Bailey CJ, Day C. 1989. Traditional plant medicines as treatments for diabetes. Diabetes Care 12: 553–564.
14) Taniguchi H, Kobayashi Hattori K, Tennmo C, Kamei T, Uda Y, Sugita-Konishi Y, Oishi Y, Takita T. 2006. Effect of Japanese radish (Raphanus sativus) sprout (Kawaiare-dakon) on carbohydrate and lipid metabolisms in normal and streptozotocin-induced diabetic rats. Phytotherapy Res 20: 274–278.
15) American Institute of Nutrition. 1977. Report of the American Institute of Nutrition ad hoc committee on standards for nutritional studies. J Nutr 107: 1340–1348.
16) Folch J, Lees M, Stanley GHS. 1956. A simple method for the isolation and purification of total lipids from animal tissues. J Biol Chem 226: 497–509.
17) Henly AA. 1957. The determination of serum cholesterol. Analyst 82: 286–287.
18) Zak B. 1957. Simple rapid microtechnic for serum total cholesterol. Am J Clin Pathol 27: 583–588.
Potential mechanism of insulin action on glucose transport in the isolated rat adipose cell. Apparent translocation of intracellular transport systems to the plasma membrane. J Biol Chem 255: 4758–4762.

Evidence that insulin causes translocation of glucose transport activity to the plasma membrane from an intracellular storage site. Proc Natl Acad Sci USA 77: 2542–2545.

Insulin-stimulated translocation of glucose transport systems in the isolated rat adipose cell. Time course, reversal, insulin concentration dependency, and relationship to glucose transport activity. J Biol Chem 256: 4772–4777.

Study of antidiabetic activity of white skinned sweet potato (Ipomoea batatas L.): comparison of normal and streptozotocin induced diabetic rats and hereditary diabetic mice. Nippon Nogeikagaku Kaishi 72: 1045–1052 (in Japanese).

Hypoglycemic effects of Atractylodis rhizoma in rats with streptozotocin-induced hyperglycemia. Korean J Pharmacol 24: 125–134.

In vitro. J Agric Food Chem 48: 849–852.

Effect of chlorophyll on plasma lipids in rats. Nippon Kaseigaku Kaishi 42: 589–594.

Lipid abnormalities in insulin resistant states. Rev Cardiovasc Med 4: 228–236.