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Effect of Cold Press Rice Berry Oil (*dark violet oil*) on Blood Glucose, Insulin level and Oxidative stress in High Fat Diet Fed to Streptozotocin-Induced Diabetic Rats

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Abstract

Diabetes mellitus is concerned as a seriously global public health problem, especially in developing countries. There has been an increasing interest in alternative therapies using plant food as an anti-diabetic agent. Rice berry oil (RBO; dark violet oil) extracted from bran of Rice Berry rice variety (*Oryza sativa*) has been described to have a high level of antioxidants and their functional properties. The aim of this study was to investigate the effect of RBO on blood glucose, insulin levels and oxidative stress in high fat (HF) diet-fed streptozotocin (STZ)-induced diabetes rats. Twenty male Sprague-Dawley rats aged six weeks (212.74 ± 15.30 g) were randomly divided into two groups; fed with normal diet and HF diet. After two weeks, two doses of STZ (20 and 30 mg/kg BW; i.p.) were injected to induce diabetes in rats fed with HF diet. Rats were considered diabetes with non-fasting blood glucose level ≥ 300 mg/dL. Rats fed with normal diet were randomly divided into two groups as for five rats per group; non-diabetes control group (NC) and non-diabetes + 5%RBO group (NR; fed normal diet but replaced oil source with 5% RBO), while STZ diabetes rats fed with HF diet were randomly divided into two groups as diabetes control group (MDC) and diabetes + 5%RBO group (DMR; fed HF diet but replaced oil source with 5% RBO). All rats were given free access to their diet and water for 12 weeks. Blood glucose, body weight and food consumption were determined and recorded every weeks. After 12 weeks, fasting blood glucose (FBG), HbA_{1c}, insulin and malondialdehyde (MDA) were measured. FBG, HbA_{1c} and MDA significantly ($p<0.05$) decreased as well as insulin concentration significantly increased in DMR group when compared to DMC group. In addition, non-fasting blood glucose at wk 12 in DMR group decreased by 38% when compared at wk 0, whereas DMC group had no significant change. The results from this study indicate that Rice berry oil can be useful as dietary supplement for improving diabetes STZ-induced rats' condition.

Keywords: diabetes, rice bran oil, rice berry, high fat diet, rats

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Introduction

The prevalence of chronic non-communicable diseases is rapidly emerging as a serious public health problem (Amos, McCarty, & Zimmet, 1997; Hossain, Kawar, & El Nahas, 2007). At least 170 million were diabetes and this figure probably would become more than double by 2030 globally (Wild, Roglic, Green, Sicree, & King, 2004). Diabetes mellitus (DM) is a chronic disease characterized by hyperglycemia resulting from absolute insufficiency of insulin secretion, insulin action or both (Alberti, Zimmet, & Consultation, 1998). The disorder in carbohydrate, fat and protein metabolism in diabetes is insufficiency of insulin on target cell (DCCT, 2004; Kuzuya et al., 2002). Hyperglycemia related to hepatic glucose production as to compensate blood glucose since insulin's action disorder. The chronic hyperglycemia is associated with adversely affects on the dysfunction and failure of various organs, especially microvascular and nerve leading to long-term complication in retina, kidney, brain and central nervous system (Alberti, et al., 1998; Kuhad, Bishnoi, Tiwari, & Chopra, 2009; Sahin et al., 2007). Rice bran is a by product or waste product from the rice milling process and also a good source of vitamins and minerals (Yu, 2010). Rice berry oil presented in this study was obtained from bran of Rice Berry Rice (dark violet grain; *Oryza Sativa*) with a cross-bred from Hom Nin Rice which well known as high antioxidant properties and Khao Dok Mali 105 which well known as fragrant rice. Rice berry oil (dark violet color) was extracted by cold press process and described as high antioxidants and properties such as: γ-oryzanol, vitamin E, β-carotene, coenzyme Q10 phenolic compounds and inhibited growth of cancer cell (Chotimarkorn, Benjakul, & Silalai, 2008; Leardkamolkarn et al., 2011; Vanavichit et al., 2007). Several studies indicated that the effect of RBO supplementation in animal was significantly decreased total cholesterol (TC) and high density lipoproteins (HDL) cholesterol ratio, nonesterified fatty acid (NEFA), triglyceride (TG), very low density lipoprotein (VLDL) and also area under the curve of insulin (Chou, Ma, Cheng, Chen, & Lai, 2009; Frank, Andrews, Elliott, Lew, & Boston, 2005; Wilson, Nicolosi, Woolfrey, & Kritchevsky, 2007). These findings show that high plasma insulin is stimulated to transport glucose into adipocyte which is the same pathway that stimulates lipid synthesis (Chou, et al., 2009). Similar to hypocholesterolemic human was shown significantly lowered plasma cholesterol, LDL-C and LDL-C/HDL-C (Berger et al., 2005). There have been suggested that γ-oryzanol and ferulic acid in rice bran oil have a strong effect against LDL oxidation and α-tocopherol has benefitial effect to inhibit lipid peroxidation

(Mäkynen K, Adisakwattana S, & Ariyapitipun T, 2010). In addition, γ-oryzanol and γ-tocotrienol in rice bran oil suppress hyperlipidemic and hyperinsulinemic response in diabetic rats (Chen & Cheng, 2006). However, few studies have determined the effect of rice bran oil in DM model and there has been no report of the beneficial effect of Rice berry oil (RBO) consumption regarding the prevention of DM.

Objective/Research Question

The purpose of this study was to investigate the effects of consumption rice bran oil extracted from Rice berry bran on blood glucose, insulin level, lipid profiles and oxidative stress in a high fat (HF) diet fed streptozotocin (STZ)-induced diabetes models of rats.

Research Methods

Preparation of Rice berry oil

Rice Berry Rice (new breeding line) obtained from cross bred between Hom Nin Rice variety and Khao Dok Mali 105. Rice berry oil (RBO) was obtained from cold press extraction of a dark violet bran of Rice Berry rice variety. The nutrient compositions and heavy metal contamination was determined (Vanavichit, et al., 2007). The Rice berry oil in this study was supplied from Knowledge Centre of Rice Science in Thailand, Kasetsart University, Kamphaeng Saen Campus, Thailand.

Animal model and treatment

All animal procedures and ethical were approved by the Experimental Animal Care and Use Committee, Faculty of Science, Mahidol University, Thailand. Twenty male Sprague-Dawley rats aged 5 weeks with a body weight of 141.10 ± 11.20 g were purchased from The National Laboratory Animal Centre, Salaya Campus, Mahidol University, Nakornpathom, Thailand. The rats were individually housed in a stanless steel cage in an air-conditioned room (23±2^{o}C, 40-50% relative humidity) with 12 hr light/dark cycle controlled room at Laboratory Animal Unit, Faculty of Science, Payathai Campus, Mahidol University, Thailand and free access to a commercial pellet diet (C.P., Thailand) and water *ad libitum* for 1 week in order to acclimate them to the facility. The normal and high fat diets were fed to each group of 10 rats for 2 weeks before DM was induced in rats fed with high fat diet. Diabetes was induced by intraperitoneal injection of STZ (20 mg/kg body weight) dissolved in citrate buffer (pH 4.5). After 3 days, this step was repeated (30 mg STZ/kg body weight) using modified method of Ming (Ming, Xiao-Yan, Jing, Zhi-Gang, & Li, 2009). Normal group was injected only by citrate buffer. One week after STZ injection, non-fasting blood glucose was checked using portable glucometer (Accu-chek Performa®, Roche Diagnostics Ltd.,Thailand) from the tip of the tail vein of each rats. At this time, non-fasting blood glucose (NFBG) was recorded for baseline data. Rats were considered diabetic with NFBG values ≥ 300 mg/dL. Rats with NFBG < 300 mg/dL were excluded from this study (MS Islam, Choi, & Loots, 2008).

The rats were then randomly divided into 4 groups with five rats in each group as shown below: normal control (NC), normal + 5%RBO (NR), diabetes control (DMC) and diabetes + 5%RBO (DMR) group. The composition of the basal diet and experimental diets (Table 1) was based on AIN-76 diet composition. Vitamin

and mineral mixture were purchased from MP Biomedicals, LLC, IIIkirch, Franch. The NR diet group was prepared by substituting with 5% rice berry oil concentration for corn oil while DMR diet was made by replace 5% rice berry oil for corn oil in the high fat diet. The rats were allowed free access to their diet and water for 12 weeks. During this period, body weight and food consumption were recorded every 3 days per week and NFBG were monitored weekly.

Groups of experimental designed:

1. NC group: normal control receive basal diet (AIN 76A)
2. NR group: normal control receive basal diet replaced corn oil with 5%RBO
3. DMC group: untreated diabetes mellitus during the study
4. DMR group: diabetes mellitus receive high fat diet supplement with 5%RBO

Table 1 Composition of basal diet (normal control) and experimental diet

Ingredient	Normal control (NC)	Normal RBO (NR)	Diabetes control (DMC)	Diabetes RBO (DMR)
Casein	20.0	20.0	20.0	20.0
Corn Starch	15.0	15.0	3.0	3.0
Sucrose	50.0	50.0	10.8	10.8
Fiber	5.0	5.0	5.0	5.0
DL-Methionine	0.3	0.3	0.3	0.3
[a]Mineral mixture	3.5	3.5	3.5	3.5
[b]Vitamin mixture	1.0	1.0	1.0	1.0
Choline Bitartrate	0.2	0.2	0.2	0.2
Corn oil	5.0	-	28.0	23.0
Rice berry oil	-	5.0	-	5.0
Water	-	-	28.2	28.2
Total	100.0	100.0	100.0	100.0

Basal diet: NC: normal group fed basal diet containing 5% corn oil; NR: normal group fed basal diet containing 5% rice berry oil; **Experimental diet:** DMC: diabetic rats fed a high fat diet containing 28% corn oil; DMR: diabetic rats fed a high fat diet containing 23% corn oil and 5% rice berry oil

[a]AIN-76 mineral mixture obtained from MP Biomedicals, LLC, lllkirch, France.

[b]AIN-76 vitamin mixture obtained from MP Biomedicals, LLC, lllkirch, France.

Blood sampling

After 12 weeks, rats were deprived of food for 12 h before collection of blood. Rats were anaesthetized with Xylazine®5 mg/kg and Zoletil® 20 mg/kg and killed by exsanguinations from the abdominal aorta (Reddy, Karuna, Baskar, & Saralakumari, 2008). Blood samples were collected from abdominal vena cava for fasting blood glucose, HbA_{1c}, insulin, lipid profiles and thiobarbituric acid substances (TBARS) analysis. Approximately 3 ml of whole blood from each rat were collected in the tube and immediately preserved at 4 ^{o}C for subsequent analysis of glycated hemoglobin (HbA_{1c}), 3 ml of whole blood were collected in EDTA tube for subsequent analysis of lipid profiles. The remaining blood was collected in the tube and centrifuged at 3,000 rpm for 10 min. The separated serum was collected and stored at -80^{o}C until further analysis.

Intraperitoneal glucose tolerance test (IPGTT)

At week 11, rats were deprived of food overnight (12 h) and injected intraperitoneally with glucose solution (2 g/Kg BW) as following the method of Islam (M Islam, 2008). Blood was drawn from a tail vein of each rats at 0 (before glucose injection), 5, 15, 30, 60, 120 and 180 min by using portable glucometer (Accu-chek Performa®, Roche Diagnostics Ltd., Thailand) which was estimated by enzyme glucose dehydrogenase diagnosis method.

Determination of non-fasting blood glucose, fasting blood glucose and HbA_{1c}

Non-fasting blood glucose was measured once a week of treatment for 12 weeks. Blood was collected from the tip of tails vein and measured by portable glucometer (Accu-chek Performa®, Roche Diagnostics Ltd., Thailand). At the end of experimental period (at week 12), rats were anaesthetized with Xylazine® 5 mg/kg and Zoletil® 20 mg/kg and blood samples were drawn from Abdominal Vena Cava.

The fasting and non fasting blood glucose was measured by portable glucometer (Accu-check Performa®, Roche Diagnostics Ltd., Thailand). HbA_{1c} was measured using automated blood sample testing instrument (Roche Diagnostics Cobas ® 6000 Analyser) and estimated by enzymatic calorimetric assay method (Shibata et al., 2000).

Determination of serum insulin

The serum insulin concentration was determined by using a rat insulin enzyme-linked immunosorbent assay kit (ELISA assay kit U-E type, Shibayaki # AKRIN-010T, Shibayagi Co. Ltd., Shibukawa, Japan) and read by microplate reader (Molecular Device Inc, CA, USA) at wavelength 620 and 450 nm (Kuhad, et al., 2009).

Determination of lipid profiles

The total cholesterol (TC), triglyceride (TG), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C) were measured using automated blood sample testing instrument (Roche Diagnostics Cobas ® 6000 Analyser), estimated by enzymatic calorimetric assay method as previously described (Shibata, et al., 2000).

Determination of oxidative stress level

Malondialdehyde (MDA) concentration in serum was measured by using TBARS assay kit (Cat No. 10009055, Cayman Chemical Company, Michigan, USA) for monitoring lipid peroxidation and read by microplate reader at 532 nm. MDA is a natural product of lipid peroxidation. The increasing of MDA value means that the body has a high oxidative stress occurring (Yagi, 1998).

Statistical analysis

All data were expressed as means ± SEM of 5 animals. Data were analyzed by statistical software (SPSS version 13 for windows). All parameters were analyzed by one-way ANOVA using the LSD's multiple-range post hoc test. Differences were considered significant at $p < 0.05$

Results

Body weight and Food intake

After feeding the experimental diet for 12 weeks, food intake was significantly higher (23.2 ± 0.45) and body weight gain was significantly lower (396.6 ± 12.84) in DMC group ($p < 0.05$). While no significant difference of body weight gain and food consumption was observed in the NC, NR and DMR as showed in Table 2. No side effect such as diarrhea or death was observed both in normal and STZ-induced diabetes rats fed the Rice berry oil.

Blood glucose and insulin level

After 12 weeks of experimental study, fasting blood glucose (FBG) and non fasting blood glucose (NFBG) were significantly decreased in DMR group compared to the DMC group (Table 2) but significantly higher concentration than both control groups ($p < 0.05$). The HbA_{1c} was also significantly decreased in the DMR group (4.99 ± 0.45) compared to the DMC group (6.80 ± 0.12) as well as serum insulin concentration was also significantly increased (409.94 ± 130.51) in the DMR group compared with the DMC group (160.69 ± 34.43). No significant difference was observed between the NC and NR group in all blood glucose and insulin value.

Table 2 Body weight, food intake, fasting blood glucose, non-fasting blood glucose, blood glycated hemoglobin (HbA_{1c}), $AUC_{glucose}$, serum insulin and serum MDA in normal control (NC), normal RBO (NR), diabetes control (DMC) and diabetes RBO (DMR) after 12 weeks of experimental period

	NC	NR	DMC	DMR
Body weight (g)	433.61 ±7.91 [a]	437.53 ± 9.95 [a]	396.60 ± 12.84 [b]	423.27 ± 9.42 [ab]
Food intake (g/d)	17.64 ± 0.62 [a]	18.15 ± 0.37[a]	23.2 ± 0.45 [b]	18.94 ± 0.15 [a]
FBG (mg/dL)	89.67 ± 5.90 [a]	100.80 ± 4.90 [a]	273.42 ± 31.17 [b]	160.42 ± 32.33 [c]
NFBG (mg/dL)	121.97 ± 1.06 [a]	123.42 ± 1.85 [a]	436.69 ± 22.22 [b]	308.38 ± 48.34 [bc]
Blood HbA_{1c} (%)	4.13 ± 0.07 [a]	4.08 ± 0.05 [a]	6.80 ± 0.12 [b]	4.99 ± 0.45 [c]
$AUC_{glucose}$ (minxmg/dL)	9593.27 ± 419.97 [a]	13221.88 ± 2147.49 [a]	45258.75 ± 4788.64 [b]	44299.58 ± 2102.71[b]
Serum insulin (pg/ml)	632.75 ± 220.63 [a]	573.81 ± 118.84 [a]	160.69 ± 34.43 [b]	409.94 ± 130.51 [a]
Serum MDA (μM)	20.29 ± 1.97 [a]	22.81 ± 1.99 [a]	35.88 ± 5.08 [b]	23.78 ± 3.17 [a]

Values are shown as mean ± SEM of 5 animals.

[a, b, c] Values with different superscript letters within a row are significantly different from each other (LSD's multiple range post hoc test, $p<0.05$)

The percent of blood glucose concentration was significantly decreased in the DMR group by 38.76 percent when compared with baseline (at week 0). In contrast, the percentage of blood glucose in the DMC group was increased around 1.7% compared

to baseline (at week 0). Meanwhile no significant different on the blood glucose change from baseline at week 0 between NC and NR group was observed as in the Figure 1.

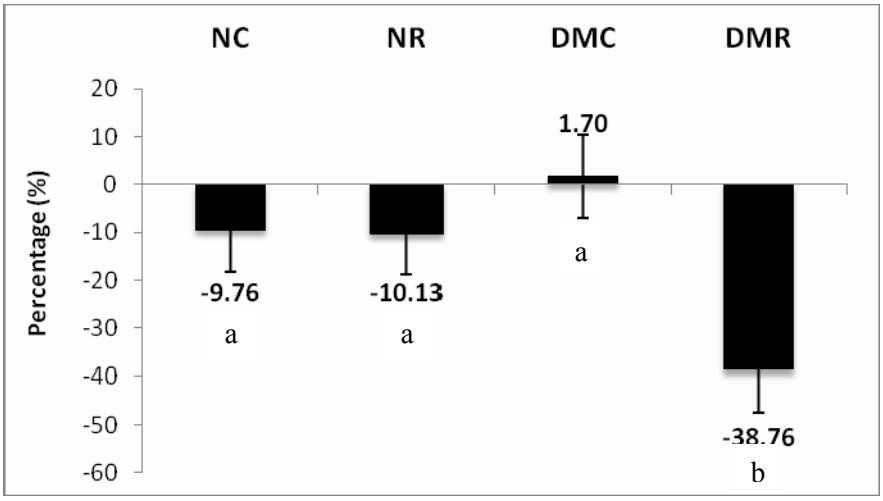

Figure 1 Comparison the percentage of blood glucose level in normal control (NC), normal RBO (NR), diabetes control (DMC) and diabetes RBO (DMR) groups between the baseline and the end of experimental period (n = 5)
[a, b, c] Values with different superscript letters for a given each bar are significantly different from each other groups (LSD's multiple range post hoc test, $p<0.05$)

Intraperitoneal glucose tolerance test (IPGTT)

The concentration of blood glucose at 0 min after glucose injection was observed with significantly higher in the DMC group (Figure2). Comparison on blood glucose value between STZ-induced diabetes rats fed with HF supplemented with or without RBO (Rice berry oil) showed that the blood glucose concentration was significantly lower in the DMR group compared to DMC group and it was significantly diminished after 60 min (Figure 2). However, the estimation of the area under the curve (AUC) for glucose in the DMR and DMC group showed that there was no significant difference between the DMR and DMC group, but the AUC of the DMR group trended to be decreasing as shown in Table 2.

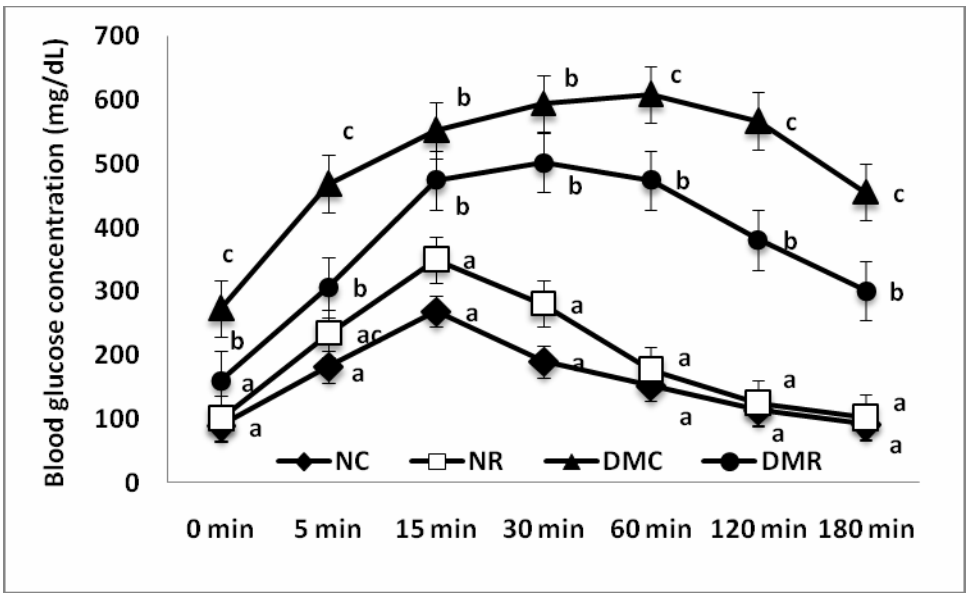

Figure 2 Intraperitoneal glucose tolerance test (IPGTT) with glucose solution (2 g/Kg BW). Blood was collected at 0 (before glucose injection), 5, 15, 30, 60, 120 and 180 min in normal control (NC; ♦), normal+RBO (NR; □), diabetes control (DMC; ▲) and diabetes+RBO (DMR; ●) groups in the last week of experimental period. Values are shown as mean ± SEM of 5 animals. [a, b, c] Values with different superscript letters for a given period of time are significantly different from each other (LSD's multiple range post hoc test, $p<0.05$)

Lipid profiles and Serum malondialdehyde (MDA)

Comparison malondialdehyde (MDA) concentration between control groups (non-diabetes rats; NC and NR) and experiment groups (diabetes rats; DMC and DMR) was found that no significant difference was observed among normal rat fed with normal diet + 5% corn oil or 5%RBO (NC and NR group) and DMR group fed with 5% RBO (20.29, 22.81 and 23.78 μM) whereas MDA concentration in the DMC group (diabetes without 5% RBO) was significantly increased (35.88 μM) as shown in Table 2. Not any change (effect) of the plasma lipid profile concentration was observed in all animal groups in the present study, even fed with RBO for 12 weeks (data not shown).

Discussion

Currently, various investigators have been used Streptozotocin (STZ) as a substance to induce diabetes together with feeding a high fat diet for established insulin resistance in rat model (Reed et al., 2000; Sahin, et al., 2007). After two weeks of a high fat consumption, two doses of STZ (20/30 mg/kg/body weight) were injected to induce diabetic symptom of rats. All diabetic rats of the present study showed higher blood glucose as well as lower insulin concentration than that of control group (MS Islam, et al., 2008; Sahin, et al., 2007). It is due to a decline of insulin production in the pancreatic islets of diabetes rats which reflects a progressive loss of β-cell function. In addition, a result of the glycated hemoglobin (HbA_{1c}) was also increase up to 6.8%. After 3 months of experimental period, all the treatment of

diabetic rats (DMR group) with 23% corn oil plus 5% rice berry oil (28% fat) containing diet showed significant improvement in many parameters such as body weight, blood glucose, insulin, glycated hemoglobin (HbA_{1c}) and MDA value with $p < 0.05$. Especially, their body weight, insulin, and HbA_{1c} were close to normal value of both control groups; however, blood glucose concentration of the DMR group was still elevated when compared to the control groups as shown in Table 2, which indicated that rice berry oil might improve diabetes condition in diabetic STZ-induce rats. This study was confirmed with the results of various parameters in the DMC group fed a HF diet containing 28% corn oil that their body weight and all blood parameter markers did not showed any improvement in diabetes symptoms such as lower body weight, greater blood glucose (273.42 ± 31.17 mg/dL) and higher HbA_{1c} (6.8 ± 0.12%) as well as lower serum insulin concentration (160.69 ± 34.43 pg/ml). This can be explained that the glucose uptake into the cell and accumulation are failed due to the β-cell dysfunction. The result from insulin production of pancreatic β-cells is not enough or disorder of insulin action is called insulin resistance (DeFronzo, 2004). Thus, blood glucose uptake and utilization by cells were impairment (Cupo & Donaldson, 1987). Therefore, the DMC rats can not use or utilize glucose from food to produce the energy to the cell so the diabetes rats in the DMC group still used fat as a source of energy which might explain why the body weight in the DMC rats were significantly lower than the other experimental groups. However, our results did not agree with a previous study which showed that plasma insulin concentration was lower in rats fed the RBO diet than that of the control group while the plasma glucose value did not differ among the experimental groups (Chen & Cheng, 2006; Srinivasan, Viswanad, Asrat, Kaul, & Ramarao, 2005). The difference in the results of the present study and previous study might be due to difference in the bioactive compound and the extraction process between the rice bran oil of previous study from our study. The rice berry oil in the present study was obtained from purple rice bran and extracted by cold press process which might contain with the stronger bioactive compounds than that of rice bran oil in the previous report, especially in the amounts of antioxidant contents such as anthocyanins, vitamin E, coenzyme Q10, γ-oryzanol, polyphenol, flavonoids and antioxidant activity which might help to improve diabetes condition (Vanavichit et al., 2009). Our finding agreed with Sasaki et al., 2007, which found that the feeding cyanidin-3-glucoside to type 2 diabetic mice showed significantly reduce in blood glucose concentration and enhance insulin sensitivity (Sasaki et al., 2007). In addition, Levine & Haft in 1970 indicated that the calculation of AUC for glucose and insulin concentration can be used for estimation of insulin sensitivity (Levine & Haft, 1970). In the present study, it was found that the AUC for glucose in the DMR group was slightly lower than that of the DMC group, however higher than that of the control group. This finding agreed with previous study that a high MUFAs diet consumption was indicated to decrease postprandial plasma glucose and insulin level in human (Parillo et al., 1992). The RBO in our study containing only 5% in diet fed in diabetes which revealed a tendency to decrease the AUC was observed in the DMR group. In the present study, the treatment of rice berry oil did not have any effect on lipid profiles even fed for 3 months. Possibly due to the level of the rice berry oil in this study fed to animal is not high in the amount to increase any impact or change in the level of the body fat because the rice bran oil of present study was used only 5% according to the requirement for animal or equal to 34 g lipid

for human consumption (Reagan-Shaw, Nihal, & Ahmad, 2008). Oberley addressed that oxidative stress plays a role in the causation of diabetes and many studies showed that antioxidants have a role in the alleviation of diabetes (Oberley, 1988). In diabetes, oxygen free radicals are generated by stimulating hydrogenperoxide in pancreatic β-cells. In general, oxygen free radicals scavenging enzymes normally respond to conditions of oxidative stress such as increasing of MDA, superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH) value with a compensatory mechanism by increase the antioxidant enzyme activity (Giugliano, Ceriello, & Paolisso, 1996; Kakkar, Kalra, Mantha, & Prasad, 1995). The results in the present study was also found that lipid peroxidation in the DMC group was significantly increased with greater value of MDA concentration while the other groups (NC, NR, and DMR), especially the DMR group which substituted with 5% rice berry oil was found that MDA concentration was near to normal control rats. This might indicated that the protective role of rice berry oil might be due to the antioxidant activities presented in the rice berry oil which act as strong superoxide radicals and singlet oxygen quenchers. Therefore the replacement or substitution of rice berry oil may help to correct the hyper or hypoglycemia and preventing diabetic complications by reduce or decrease lipid peroxidative stress and free radical oxidation. This finding agreed with a previous study that oxidative stress was also found in the multiple tissues of diabetes rats (Hsieh et al., 2005). In the present study, MDA in diabetes supplemented with 5% RBO (DMR group) was decreased ($p<0.05$) which may result from the role of antioxidant activity containing in rice berry oil, especially anthocyanins, γ-oryzanol, ferulic acid, coenzyme Q10, α-tocopherol and/or flavonoid content. It has been recently reported that α-tocopherol and tocotreinol extracted from rice bran oil helped protect against the oxidative damage in diabetic mice (Kanaya et al., 2004).

In conclusion, the consumption of rice berry oil resulted in a significantly decrease in blood glucose, oxidative stress and increase insulin concentration as well as insulin sensitivity in high fat diet fed STZ-induced diabetic rats. Therefore, the supplementation with rice berry oil may be beneficial for improving the hypo or hyperglycemia and help to improve diabetes complications from a role of lipid peroxidation or free radical oxidation.

Suggestions

The results from this study suggest that 5%RBO may increase insulin secretion and improve insulin response as well as ameliorate blood glucose and MDA level in diabetic rats. Rice berry oil can be useful as dietary supplement for improving diabetes STZ-induced rats' condition.

Further study need to clarify and study in diabetes patients.

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