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Oat oil lowers the plasma and liver cholesterol concentrations by promoting the excretion of faecal lipids in hypercholesterolemic rats

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ABSTRACT

The aim of the present study is to investigate the hypocholesterolemic effect of dietary oat oil in rats, fed with a hypercholesterolemic diet. The rats were divided into three groups and fed with the experiment diets for 30 days, containing soybean oil, oat oil, or rice bran oil at a dose of 70 g/kg. It was found that the oat oil lowered plasma total and LDL-cholesterol, and also reduced liver total, free cholesterol, cholesterol ester, and triglycerides concentrations significantly, as well as rice bran oil. Moreover, the faecal weight, total lipids, and bile acids concentrations, in the oat oil and rice bran oil groups, were significantly increased compared with that in the soybean oil group. We can conclude that dietary oat oil improves hypercholesterolemia in rats fed a hypercholesterolemic diet, by promoting excretions of faecal lipids and bile acids.

1. Introduction

It is well known that hypercholesterolemia is a risk factor for the development of cardiovascular diseases (CVDs), which is the primary leading cause of human death in the United States of America (Rosamond et al., 2008). Prevention of CVD by alternative medicinal foods is receiving increasing interest from scientists. Oat is well-known for its highly nutritious content and notable health benefits. Dietary oat has been reported to improve symptoms associated with coronary heart disease (Berg et al., 2003), serum cholesterol (Chen, He, Wildman, Reynolds, & Streiffer, 2006), diabetes (Tapola, Karvonen, Niskanen, Mikola, & Sarkkinen, 2005), and obesity (Zduńczyk et al., 2006). Moreover, previous research indicates that oat bran, taken daily, can significantly lower serum cholesterol and triglyceride levels in the young healthy population (Gold & Davidson, 1988; Romero, Romero, Galaviz, & Fernandez, 1998).

In addition, Gerhardt and Gallo (1998) demonstrated that dietary full-fat oat bran and rice bran, similarly lower serum total cholesterol and low-density lipoprotein (LDL)-cholesterol levels. Numerous studies in humans and animals have shown dietary fat is the most critical factor in lowering plasma lipids, and there is sufficient evidence to support that the rice bran oil reduces serum cholesterol levels and prevents CVD effectively compared with other vegetable oils (Lichtenstein et al., 1994; Most, Tulley, Morales, & Lefevre, 2005; Sugano & Tsuji, 1997). However, little research focuses on the effect of oat oil on the reduction of hypercholesterolemia.

The major nutritious contents in oat have been widely reported, and these include 2–12% crude fat (Aro, Järvenpää, Könkö, & Hietaniemi, 2007), 13–20% proteins (Mirmoghtadaie, Kadivar, & Shahedi, 2009), about 60% starch (Hoover, Smith, Zhou, & Ratnayake, 2003), and β-glucan 2.0–7.5% (Andersson & Börjesdotter, 2011). Besides, oat oil has also been shown to possess nutritional and technological potential (Zhou, Robards, Glennie-Holmes, & Helliwell, 1999). Compared with other cereal grain, oat contains much higher levels of crude fat which makes oat an excellent source for functional food applications (Molteberg, Vogt, Nilsson, & Frølich, 1995; Saastamoinen, Plaami, & Kumpulainen, 1992; Zhou et al., 1999), however, oats have not been used as a source of edible oil.

In the present study, oat oil was isolated by supercritical carbon dioxide extraction from oat (*Avena sativa* L.) flour, and its total fatty acid, vitamin E and sterols contents were determined. To investigate the effects of oat oil on the cholesterol metabolism in Wistar–Lewis rats, fed a hypercholesterolemic diet, oat oil was fed to rats in order to elevate the serum cholesterol concentrations (Nath, Wiener, Harper, & Eicvehjem, 1959).

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2. Materials and methods

2.1. Materials

Oat (*A. sativa* L.) seeds were provided by Hebei Academy of Agriculture and Forestry Sciences (Hebei, China). Soybean oil was provided by BEIJING HFK BIOSCIENCE Co., Ltd. (Beijing, China). Rice bran oil was purchased from shanghai kerry oils & grains industrial Co., Ltd. (Shanghai, China).

2.2. Isolation of oat oil

Oat oil was extracted from milled samples through the method of supercritical carbon dioxide ($SCCO_2$) extraction using a Supercritical Carbon Dioxide Extractor (Nantong Huaan super critical extraction Co., Ltd., Nantong, China). The extraction of oat oil was performed as follows: pressure 35 MPa, temperature 55 °C, and extraction time 4 h (Fors & Eriksson, 1990). The extracted oat oil was stored at −20 °C for further analysis of the fatty acid, tocopherol and sterol.

2.3. Total fatty acid composition analysis

The total fatty acid composition of oil was analyzed by gas–liquid chromatography (ISO 5508, 1990). In brief, the oat oil was transmethylated with a sulphuric acid/methanol mixture (1:99, v/v) into fatty acid methyl esters, under liquid nitrogen at 80 °C for 2 h. Hexane and saturated NaCl were added to get the mixture which was divided into two layers by centrifugation at 2000*g* for 10 min. The fatty acids–hexane layer was collected for the next experiments. The fatty acids methyl esters were determined by gas–liquid chromatography (450-GC, Varian Ltd., Salt Lake, USA) with a CP-Wax 57 CB capillary column (50 m × 0.32 mm × 0.20 μm, Varian Ltd., Salt Lake, USA). The column temperature was 200 °C. The temperature of the injector or flame ionization detector was 250 °C. Hydrogen was used as carrier gas at a flow rate of 65 cm/s.

2.4. Sterol content analysis

The sterol content of oil was determined by the method of UNI EN ISO 12228 (1999). Briefly, the oat oil was transmethylated with a sulphuric acid/methanol mixture as mentioned above. The sterols were derivatized to trimethylsilyl ethers and its quantification by gas–liquid chromatography with a CP-Wax 57 CB capillary column was performed, as follows: the column temperature was set at 100–235 °C (10 °C/min); 0.5 min isotherm; the column temperature was set at 235–300 °C (10 °C/min); 3 min isotherm; injector 300 °C; flame ionization detector 320 °C. 5α-cholestane (Sigma, USA) was used as the internal standard.

2.5. Vitamin E content analysis

The α-tocopherol, β-tocopherol, γ-tocopherol, δ-tocopherol, α-tocotrienol, and γ-tocotrienol contents of oil were determined by high-performance liquid chromatography (HPLC), equipped with an ultraviolet detector according to the method of Panfili, Fratianni, and Irano (2003) with some modifications. The kromasil YMC-Pack SIL column (25 × 4.6 mm I.D., S-5 μm, 12 nm, YMC Co., Ltd., Kyoto, Japan) was used, and an isocratic elution was performed using *n*-hexane/isopropanol (99:1), at a flow rate of 1.0 ml/min. All peaks were detected at 290 nm. Standard was from Solarbio (Solarbio Science & Technology Co., Ltd., Beijing).

2.6. Animals and diets

Four-week-old male Wistar–Lewis rats ($n = 27$) were obtained from Vital River Lab Animal Technology Co., Ltd. (Beijing, China). All rats, housed individually in stainless steel cages, were acclimatized to the laboratory conditions (22 ± 2 °C, 55 ± 5% humidity, and 12 h light/dark cycle), for 1 week prior to the experiment. Rats were divided into three groups (Control, oat oil, and rice bran oil) so that the average body weight was the same for each group. The rats were fed three diets, and given deionized water ad libitum for 30 days. Experimental diets were prepared according to the American Institute of Nutrition (AIN)-93G formula with some modifications. The composition of the diets is shown in Table 1.

The blood samples were taken from the eye-veniplex on the 0th, 10th, and 20th day, respectively. Rat faeces were collected for 3 days before the rats were sacrificed. The rats were fasted for 16 h and then sacrificed by the removal of blood from the abdominal aorta. Livers frozen by liquid nitrogen were kept at −20 °C until analysis.

All experiments were carried out according to the PR China legislation regarding the use and care of laboratory animals and were approved by the Bioethics Committee of the Institute of Medicinal Plant Development, Chinese Academy of Medical Sciences and Peking Union Medical College.

2.7. Analysis of metabolic parameters in rats

The concentration of serum lipids was measured using an Automatic Chemistry Analyzer (Hitachi, Tokyo, Japan). The concentration of liver lipids was measured with commercially available kits (Tissue total cholesterol assay kit, E1015, Tissue free cholesterol assay kit, E1016, and Tissue triglyceride assay kit E1003-2 from Applygen Technologies Co., Ltd., Beijing, China). The faecal bile acid content and cholesterol content were measured using the Rat Bile Acid ELISA kit from Nanjing Sen Shellfish Gamma Biotechnology Co., Ltd. (Nanjing, China) and Tissue total cholesterol assay kit, E1015 from Applygen Technologies Inc., Beijing, China, respectively. The faecal total lipids were measured by the Soxhlet method.

2.8. Statistical analysis

The data was expressed as means with standard errors and analyzed by the Tukey–Kramer's multiple comparison post hoc test.

Table 1
Diet composition (g/1000 g diet).

	Control	Oat oil	Rice bran oil
Casein	200	200	200
Corn starch	397	397	397
Soybean oil	70		
Oat oil		70	
Rice bran oil			70
Cellulose	50	50	50
Sucrose	38.5	38.5	38.5
t-Butylhydroquinone	0.014	0.014	0.014
Choline bitartrate	2.5	2.5	2.5
L-Cystine	3	3	3
Maltodextrin 10	132	132	132
Mineral mix	35	35	35
Vitamin mix	10	10	10
Cholesterol	10	10	10
Bile salt	2	2	2
Lard	50	50	50

The diets were prepared according to the AIN-93G formula with some modifications.