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Original Article

Red algae (*Gelidium amansii*) hot-water extract ameliorates lipid metabolism in hamsters fed a high-fat diet

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ABSTRACT

The purpose of this study was to investigate the effects of *Gelidium amansii* (GA) hot-water extracts (GHE) on lipid metabolism in hamsters. Six-week-old male Syrian hamsters were used as the experimental animals. Hamsters were divided into four groups: (1) control diet group (CON); (2) high-fat diet group (HF); (3) HF with GHE diet group (HF + GHE); (4) HF with probucol diet group (HF + PO). All groups were fed the experimental diets and drinking water *ad libitum* for 6 weeks. The results showed that GHE significantly decreased body weight, liver weight, and adipose tissue (perirenal and paraepididymal) weight. The HF diet induced an increase in plasma triacylglycerol (TG), total cholesterol (TC), low-density lipoprotein cholesterol and very-low-density lipoprotein cholesterol levels. However, GHE supplementation reversed the increase of plasma lipids caused by the HF diet. In addition, GHE increased fecal cholesterol, TG and bile acid excretion. Lower hepatic TC and TG levels were found with GHE treatment. GHE reduced hepatic sterol regulatory element-binding proteins (SREBP) including SREBP 1 and SREBP 2 protein expressions. The phosphorylation of adenosine monophosphate (AMP)-activated protein kinase (AMPK) protein expression in hamsters was decreased by the HF diet; however, GHE supplementation increased the phosphorylation of AMPK protein expression. Our results suggest that GHE may ameliorate lipid metabolism in hamsters fed a HF diet.

1. Introduction

A diet high in fat may cause hyperlipidemia, which is characterized by elevated plasma levels of total cholesterol (TC), triacylglycerol (TG), and low-density lipoprotein cholesterol (LDL-C) [1,2]. All of these symptoms are known to be major risk factors for developing cardiovascular disease [3] and nonalcoholic fatty liver disease [4,5].

Scientists recently demonstrated that algae can play some beneficial effects on the improvement of hyperlipidemia, nonalcoholic fatty liver disease, and obesity. *Chlorella pyrenoidosa*, a type of green algae, has been shown to lower serum TC, TG, and LDL-C in rats and hamsters [6]. In addition,

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Ecklonia cava, an edible brown algae, is effective in reducing adipose tissue, plasma TC concentration, and liver TG content in mice [7]. Moreover, brown seaweed extracts can decrease serum TG levels and liver fat contents in obese nondiabetic women [8]. These results indicate that algae may play a critical role in regulating lipid metabolism in animals and humans.

Gelidium amansii (GA) is an edible red algae that is widely distributed in Japan, Korea, China, and northeast Taiwan. Agar jelly made from hot-water extracts of GA is a traditional desert in Taiwan and Japan. Our previous study demonstrated that supplementation with GA powder in a high-fat (HF) and high-cholesterol diet can reduce plasma and liver lipids in diabetic rats [9]. It was suggested that the abundance of water-soluble fiber in GA was an active component in reducing lipid accumulation in liver and adipose tissue. Other studies have shown that ethanol extracts of GA can inhibit lipid accumulation in 3T3-L1 cells [10], and decrease body weight, epididymal fat weight, and serum TC and TG levels in obese mice [11]. These results indicate that GA, including both water-soluble components (e.g., water-soluble polysaccharides) and water-insoluble components (e.g., flavonoids), may have beneficial effects on the improvement of lipid metabolism. However, the active component and mechanism of action of the lipid-lowering effect of GA is still unclear.

In Taiwan, GA is traditionally processed by exposure to sunlight followed by extraction with hot water. However, this process may result in a loss of phytochemicals and, therefore, the water-soluble fiber in GA is suggested to play a role in regulating lipid metabolism [9]. Cholesterol and bile acid metabolism of hamsters have been reported to closely resemble that of humans, and thus are considered as a suitable animal model for studying lipid metabolism [12,13]. In the present study we further investigated the effect of the hot-water extract of GA on lipid metabolism in hamsters fed a HF diet, and evaluated its possible mechanism of action.

2. Materials and methods

2.1. GA hot-water extract

GA (Lamouroux) (dry material) was purchased in the market at Keelung, the northeast corner of Taiwan. It was stored at 4°C until used. A 20-g quantity of GA was added to 400 mL of deionized water and autoclaved at 121°C for 20 min. After cooling, the GA hot-water extract (GHE) was filtered through filter paper No. 1 (Advantec. Toyo Roshi Kaisha, Ltd., Tokyo, Japan) and then lyophilized. The harvest weight of hot-water extracts obtained from 20 g GA was 5.71 g (recovery about 28.5%). General compositions of GHE were determined using the methods of the Association of Official Agricultural Chemists (AOAC) [14], including moisture, 6.5%; ash, 4.6%; crude fat, 0.25%; and crude protein, 6.7%. In addition, according to analysis by the Food Industry Research and Development Institute, Hsinchu, Taiwan, GHE contains 68.6% water-soluble dietary fiber and 0% water-insoluble dietary fiber [14]. Moreover, GHE contains 4.1% sulfate (in dry weight). Sulfate content in GHE was determined by the rhodizonate method using sodium sulfate as standard [15].

2.2. Animals and treatments

Six-week-old male Syrian hamsters were purchased from The National Laboratory Animal Center (Taipei, Taiwan). Hamsters were housed in individual stainless steel cages in a room kept at 23°C ± 1°C and 40% to 60% relative humidity, with a 12-h light–dark cycle. Hamsters were fed a standard laboratory diet (5001 rodent diet, Lab Diet, PMI Nutrition International Inc., Brenwood, MO, USA) for 1 week and were then divided into four groups of eight hamsters each. The four groups were as follows: (1) normal diet group [control (CON)]; (2) HF diet group (HF group); (3) HF diet with 1.5% GHE group (HF + GHE group); and (4) HF diet with 1% probucol (Sigma St. Louis, MO, USA) group (HF + PO group). The daily dose of probucol in the HF + PO group was approximately equivalent to 640 mg/kg body weight. Probucol is an antihyperlipidemic drug developed in the treatment of coronary artery disease, which can decrease blood and liver cholesterol in animals and humans [16–18]. The composition of the normal control diet was 5001 rodent diet. Our previous study showed that hamsters fed a diet containing 3% Ching-Shan oil and 0.2% cholesterol can have increased plasma and liver lipid levels [19]. In the present study, the HF diet contained 94.9% (w/w) normal diet, 5% (w/w) Ching-Shan oil, and 0.1% (w/w) cholesterol. The composition of the four diets is shown in Table 1.

The hamsters were fed the experimental diets for 6 weeks. Food and drinking water were available *ad libitum*. Body weight was measured every week and feces were collected during the final 3 days of the experiment. The feces samples were then dried and weighed. This study was approved by the Animal House Management Committee of the National Taiwan Ocean University. The animals were maintained in accordance with the guidelines for the care and use of laboratory animals as issued by the Animal Center of the National Science Council.

2.3. Collection of blood and tissue samples

At the end of the experiment, hamsters were fasted overnight and then sacrificed by exsanguination via the abdominal aorta while under CO_2 anesthesia. Heparin was used as the anticoagulant. Plasma was collected by centrifugation at 1750*g* for

Table 1 – Composition of the experimental diet (%).

Ingredient (%)	CON	HF	HF + GHE	HF + PO
Chow diet	100	94.9	93.4	94.9
Ching-Shan oil[a]	0	5	5	5
Cholesterol	0	0.1	0.1	0.1
Gelidium hot extract	0	0	1.5	0
Total	100	100	100	100
Probucol	—	—	—	1
Total energy Kcal/100 g	336.0	363.9	362.1	363.9

CON, normal diet group; HF, high-fat diet group; HF + GHE, *Gelidium amansii* hot-water extract diet group; HF + PO, probucol diet group.

[a] Ching-Shan oil: a mixture oil of palm oil, lard, and canola oil. In addition, Ching-Shan oil contains saturated fat (32.7%) and cholesterol (162 mg/100 g). The fatty acid composition of Ching-Shan oil is: 14:0 (1.9%); 16:0 (29.3%); 16:1 (2.8%); 18:0 (8.3%); 18:1 (42.5%); 18:2 (14.8%); 18:3 (0.4%).