Dietary Diacylglycerol Induces the Regression of Atherosclerosis in Rabbits\textsuperscript{1,2}

Noriyasu Ota,\textsuperscript{*} Satoko Soga, Tadashi Hase, Ichiro Tokimitsu, and Takatoshi Murase

Biological Science Laboratories, Kao Corporation, Tochigi 321-3497, Japan

Abstract

Recent studies of the relation between serum triacylglycerol concentration and the risk for coronary artery disease suggest that inefficient clearance of postprandial triacylglycerols promotes atherogenesis. We recently demonstrated that dietary diacylglycerol (DAG), rich in the 1,3-isomers, suppresses the postprandial increase in serum triacylglycerol levels compared with dietary triacylglycerol (TAG). Here, we investigated the effects of dietary DAG on atherosclerosis in rabbits with cholesterol-induced atherosclerosis. New Zealand White rabbits (n = 20) were fed a diet containing 3% lard and 1.3% cholesterol for 50 d to induce atherosclerotic lesions. Thereafter, the rabbits were assigned to 2 groups and fed 90 g/d nonpurified diet and orally administered 5 g DAG or TAG for an additional 34 d. Reference rabbits (n = 5) were fed only the nonpurified diet throughout the 84-d study. The area of atherosclerotic lesions and aortic lipid concentrations were significantly lower in DAG-fed rabbits compared with TAG-fed rabbits. The VLDL receptor and macrophage antigen-1 mRNA expression levels were significantly lower in DAG-fed rabbits than in TAG-fed rabbits. In the liver of DAG-fed rabbits, the triacylglycerol concentration was lower and the carnitine palmitoyltransferase activity higher than in TAG-fed rabbits. Stimulation of hepatic lipid catabolism might be related to the reduced lipid accumulation in the liver and aorta by reducing the release of triacylglycerol into the circulation. Thus, long-term consumption of DAG, which reduces postprandial lipemia, might be useful for the regression of atherosclerosis by stimulating hepatic lipid catabolism and thereby modulating monocyte/macrophage migration and aortic lipid accumulation. J. Nutr. 137: 1194–1199, 2007.

Introduction

The importance of serum triacylglycerols as a risk factor for coronary artery disease (CAD\textsuperscript{1}) is a matter of intense debate. Epidemiologic studies indicate that hypertriglyceridemia is an independent risk factor for CAD (1). Triacylglycerol-rich lipoproteins are a heterogeneous population of particles varying in origin, structure, and atherogenic properties. Recent studies demonstrated that postprandial triacylglycerol-rich lipoproteins (chylomicrons, VLDL, and their remnants) are related to the risk of CAD, and suggest that inefficient clearance of postprandial triacylglycerol promotes atherogenesis (2). Lipoproteins and their remnants induce platelet aggregation, impair endothelium-dependent coronary vasodilation, and induce monocyte-endothelium adhesion, which are crucial steps in atherogenesis (3). Serum triacylglycerol concentrations increase after the ingestion of a meal containing fats, and the postprandial response takes up to 8 h (4). Therefore, humans usually spend most of their lives in the postprandial state. Elevated postprandial lipemia contributes to the progression of CAD; therefore, it is important to avoid excess triacylglycerol in the blood during the postprandial phase. A number of physiologic and nutritional factors affect the magnitude of the postprandial lipemic response (5). Dietary fiber (6), glucose (7), and soybean protein (8) reduce the magnitude of postprandial lipemia.

Diacylglycerol (DAG) is an intermediate in the process of triacylglycerol digestion and absorption. DAG, which is comprised of \(-10\%\) various dietary oils, is widely consumed in our daily diet. Studies of the nutritional characteristics and effects of DAG rich in 1,3 isomers, in comparison with dietary triacylglycerol (TAG), indicate that DAG has beneficial effects with regard to the prevention and management of obesity and postprandial lipemia (9–12). In double-blind placebo-controlled studies, DAG decreased body weight and abdominal fat mass in humans (9,10) and prevented the accumulation of body weight and fat associated with a high-fat and high-sucrose diet in obesity-prone mice (11). Tada et al. (12) reported that after a single dose of DAG emulsion, the increase in postprandial serum remnant-like lipoprotein lipid concentration was smaller than that observed after the administration of TAG emulsion. More recently, Mori et al. (13) reported that oral DAG loading reduced postprandial lipemia in type 2 diabetic Otsuka Long-Evans Tokushima Fatty rats. These results indicate that DAG might be beneficial for the treatment of atherosclerosis by...
Fatty acid composition

Materials and Methods

Test oils. DAG was prepared by esterifying glycerol with fatty acids from natural vegetable oils using a reverse reaction of immobilized lipase (15). This DAG was composed of 1,3-DAG and 1,2-DAG isomers at a ratio of 7:3. After analysis of the fatty acid profile of the DAG, the control TAG was blended from a combination of rapeseed oil and sunflower oil to generate a similar fatty acid profile (Table 1).

Animals and diets. Twenty-five male New Zealand White rabbits (Oriental Yeast) weighing between 1.50 and 1.99 kg were used. They were housed individually at 23°C under a 12-h light-dark cycle and had free access to water and food. The rabbits were randomly assigned to 2 groups. One group (n = 5) served as a reference group and was fed a nonpurified diet (CR-3: Clea Japan) for 50 d. Another group (n = 20) was fed 90 g/d (78.8 kJ) of an atherogenic diet (95.7% nonpurified diet, 3% lard, and 1.3% cholesterol) to provoke an atherosclerotic process (14) for 50 d. After the 50-d period (d 0), the rabbits in the atherogenic diet group were further divided into 2 groups: the DAG and TAG groups. These 2 groups were matched for serum triacylglycerol (2.02 ± 0.33 vs. 1.97 ± 0.35 mmol/L), cholesterol levels (64.6 ± 7.8 vs. 64.7 ± 5.4 mmol/L), and body weight (2.7 ± 0.04 vs. 2.7 ± 0.04 kg), respectively. Previous studies using a high cholesterol and lard diet for 50 d documented increased levels of plasma cholesterol, which is associated with the development of atherosclerotic lesions (14,16,17). The rabbits in both the DAG and TAG groups were fed 90 g/d of nonpurified diet or orally administered 5 g of DAG or TAG, respectively, once daily (within 20 min) via a plastic syringe in a restraining cage (18) for an additional period of 34 d. The reference group continued to be fed the nonpurified diet. Blood samples were obtained from the ear vein once a week, after the rabbits were deprived of food overnight.

At the end of the experimental period (d 34), the rabbits were killed with an overdose of pentobarbital. The liver and aorta from the diaphragm were dissected. Fats and tissue adhering to the adventitia were removed and the aorta was opened longitudinally. The remaining tissue from segment 1 (aortic arch (2a) and thoracic aorta (2b)). Segments 2a and 2b were frozen in liquid nitrogen and used for RNA extraction and real-time PCR analysis.

This study was approved by the Animal Care Committee of Kao Tochigi Institute.

Serum lipids and lipoproteins. Serum was separated by centrifugation at 1750 × g for 10 min. Serum lipoprotein fractions were separated by ultracentrifugation (19). VLDL was in the d < 1.006 kg/L fraction, and HDL was in the d > 1.060 kg/L fraction. LDL was calculated by subtracting the d > 1.060 kg/L fraction from the d > 1.006 kg/L fraction. Serum triacylglycerols (Triglyceride E-test) and total cholesterol (Cholesterol E-Test) were measured using the enzymatic procedures of commercial kits (Wako). The atherogenic index (AI) was calculated using the following formula: AI = (total cholesterol – HDL cholesterol)/HDL cholesterol (20).

Evaluation of atherosclerotic lesions. The extent of the atherosclerotic lesions was estimated using image processing software (21). Segment 1 was stained with Oil red O for 20 min. After washing, the Oil red O-positive area was measured as the percentage of lesion area to the total internal surface area of segment 1. Next, segments 1a (proximal section), 1b (aortic arch), and 1c (thoracic aorta) were embedded in paraffin and used for histologic and immunohistochemical analysis (22). The sections were stained with Sudan or immunostained with anti-macrophage antibody (RAM11, Dako) using an avidin/biotin/alkaline phosphatase system (Vector Laboratories). The extent of lipid accumulation was calculated as the percent Sudan-positive area to the total cross-sectional area.

Aorta and liver lipid analysis. The remaining tissue from segment 1 (segment 1d) was used for lipid extraction. Aorta and liver lipids were extracted and purified with methanol/chloroform (1:2). The extracts were dissolved in chloroform, diluted in 10% Triton X-100/2-propanol, followed by measurement of the triacylglycerol and total cholesterol concentrations using commercial kits as described above.

RNA extraction and quantitative real-time PCR. Total RNA was isolated using Isogen (Wako) according to the manufacturer’s instructions. Reverse transcription was performed with oligo d(T)18. The extent of differential gene expression in the aortic arch and thoracic aorta tissues was investigated using real-time PCR with SYBR Green PCR Master Mix (Applied Biosystems) (23). The real-time PCR reactions were performed in an ABI PRISM model 7000 sequence detector (Applied Biosystems) under the following conditions: 50°C for 2 min, 95°C for 10 min, followed by 40 cycles at 95°C for 5 s and 60°C for 1 min. The primers used were: vascular cell adhesion molecule (VCAM)-1 F: 5′-CAAAAGGAGAGTACACCAATCCT-3′; VCAM-1 R: 5′-AGG-GACTGACCAAGCAGTATAT′-3′ (GenbankAY212510); lectin-like oxidized LDL receptor (LOX)-1 F: 5′-GGAGGAAACCCGACTACTCTATG-3′; LOX-1 R: 5′-GCACCCTTGAAATCTGACAAG-3′ (AB016237); macrophage antigen-1 (Mac-1) F: 5′-GGTCATCTGGAGGCTGCTG-3′; Mac-1 R: 5′-ACTGGAGTCGAGCTCTCCCTCCT-3′ (BC005861); macrophage scavenger receptor type-1 (SR) F: 5′-CTITGTTGCTGTGGTCTCTATTCC-3′; SR R: 5′-TGCAATCTTCTCATTCCCACACACTC-3′ (D13381); VLDL receptor (VLDLr) F: 5′-AACCCTTGAGGATATTGACAA-3′; VLDLr R: 5′-TGAAAGTGCTTATTAAGTGTACAA-3′ (D11100); and 36B4 F: 5′-TATCCATGTGGCTCTCCCTCC-3′; 36B4 R: 5′-ATTCTTAATGGTCCCTCTG-3′ (X15267).

The mRNA levels were calculated relative to the 36B4 mRNA levels. Normalized values were expressed as percentages, using the the reference group as 100%.

Liver enzyme activities. Frozen liver was thawed and homogenized on ice with 5 volumes of 250 mmol/L sucrose containing 1 mmol/L EDTA and 10 mmol/L HEPES (pH 7.2), and centrifuged at 500 × g for 10 min. The supernatant fraction was re centrifuged at 9000 × g for 10 min. Carnitine palmitoyltransferase (CPT) activity was measured using the 500 × g supernatant fraction, and fatty acid synthetase (FAS) activity was measured in the 9000 × g supernatant fraction of the liver homogenate (24).

TABLE 1 Acylglycerol and fatty acid compositions of the test oils

<table>
<thead>
<tr>
<th>Acylglycerol species</th>
<th>DAG oil</th>
<th>TAG oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monaclylglycerol</td>
<td>0.5</td>
<td>ND</td>
</tr>
<tr>
<td>Diacylglycerol</td>
<td>84.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Triacylglycerol</td>
<td>13.8</td>
<td>97.7</td>
</tr>
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</table>

Fatty acid composition

1 ND, not detected.

Dietary diacylglycerol and atherosclerosis 1195

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CPT activity was measured spectrophotometrically in the liver homogenates according to the method of Markwell et al. (25). FAS activity was also determined spectrophotometrically by the method of Kelley et al. (26), with minor modifications. The reaction mixture contained 0.2 mol/L potassium phosphate buffer (pH 7.0), 2.5 mmol/L acetyl-CoA, 10 mmol/L NADPH, 10 mmol/L malonyl-CoA, and 300 μg protein. The rate was followed at 340 nm on a spectrophotometer at 30°C for 3 min. Protein concentrations were measured using the Cytoskeleton Advanced Protein Assay Reagent (Cytoskeleton).

**Statistical analysis.** All values are presented as means ± SE. Student’s t test was used for comparisons between DAG and TAG groups. If the variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s test was used for comparisons between DAG and TAG groups. If the Student’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level). Differences of variance was unequal, Welch’s t test was used (AI, aorta cholesterol concentration, and thoracic aorta VLDLr mRNA level).

**Results**

**Food intake and body weight.** Atherogenic diet-fed rabbits ingested DAG or TAG for 34 d. The oil intake did not significantly differ between groups (data not shown). Body weight at the end of the experiment did not differ between the DAG (4.42 ± 0.04 kg) and TAG (4.37 ± 0.06 kg) groups.

**Serum lipids.** At the beginning of the test oil ingestion period (d 0), serum triacylglycerol (Fig. 1A) and total cholesterol (Fig. 1B) concentrations did not differ between the DAG and TAG groups. After 34 d, concentrations of both lipids had decreased in the groups (P < 0.05), but neither concentration differed between the DAG and TAG groups at any time. However, the decrease in serum total cholesterol between d 7 and d 15 in the DAG group (15.8 ± 2.7 mmol/L) was greater (P < 0.05) than that of the TAG group (7.8 ± 2.0 mmol/L).

**Liver lipids and enzyme activities.** Liver triacylglycerol, but not cholesterol concentration, in the DAG group was lower (P < 0.001) than that of the TAG group (Table 2). The activity of CPT, an enzyme involved in the β-oxidation pathway that is necessary for the utilization of fatty acids by the mitochondria, was higher (P < 0.05) in the DAG group than in the TAG group (Table 4). In contrast, although FAS activity was lower in rabbits fed the atherogenic diet than in the reference group, it did not differ between the DAG and TAG groups (Table 4).

**Histologic analysis and mRNA expression.** The ratio of the aortic arch Sudan-positive areas of the DAG group was lower (P < 0.05) than that of the TAG group (Fig. 2). In addition, massive RAM11-positive macrophages were detected in the intimal lesion in the TAG group.

**Discussion**

In this study, we examined the effects of dietary DAG in rabbits with diet-induced atherosclerosis. The area of atherosclerotic lesions and the amount of aortic lipid accumulation were lower

### TABLE 2

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>DAG</th>
<th>TAG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aorta</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triacylglycerol</td>
<td>0.155</td>
<td>0.141</td>
<td>0.254</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0.019</td>
<td>0.074</td>
<td>0.191</td>
</tr>
<tr>
<td><strong>Liver</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triacylglycerol</td>
<td>0.170</td>
<td>0.131</td>
<td>0.239</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0.028</td>
<td>0.454</td>
<td>0.507</td>
</tr>
</tbody>
</table>

1. Values are means ± SEM. n = 5 (Reference) or n = 10 (TAG). Asterisks indicate different from DAG: *P < 0.05, **P < 0.01.

2. Nonatherosclerotic rabbits were included for reference only.
Thoracic aorta represents 1 mm. Wall of the aorta are lesions visualized by Sudan staining. The bar represents 1 mm.

in DAG-fed rabbits than in TAG-fed rabbits. Immunohistochemical analysis revealed that the macrophage-positive area in the atherosclerotic lesions of DAG-fed rabbits was smaller than that in TAG-fed rabbits. Moreover, mRNA expression levels of Mac-1 and VLDLR, which reflect the smooth muscle cell and macrophage infiltration in atherosclerotic lesions, were significantly lower in DAG-fed rabbits than in TAG-fed rabbits. These results suggest that dietary DAG might induce regression of atherosclerosis.

Various dietary oils are reported to prevent atherosclerosis (14). Fish oils, in particular, help to prevent the progression of atherosclerosis. Various dietary oils are reported to prevent atherosclerosis (14). Fish oils, in particular, help to prevent the progression of atherosclerosis. Dietary diacylglycerol and atherosclerosis

### FIGURE 2
Histologic analysis of atherosclerotic lesions in aorta. Serial sections of the aortic arch in atherosclerotic rabbits orally administered DAG (A) or TAG (B) for 34 d. Dark staining areas in the wall of the aorta are lesions visualized by Sudan staining. The bar represents 1 mm.

in DAG-fed rabbits than in TAG-fed rabbits. Immunohistochemical analysis revealed that the macrophage-positive area in the atherosclerotic lesions of DAG-fed rabbits was smaller than that in TAG-fed rabbits. Moreover, mRNA expression levels of Mac-1 and VLDLR, which reflect the smooth muscle cell and macrophage infiltration in atherosclerotic lesions, were significantly lower in DAG-fed rabbits than in TAG-fed rabbits. These results suggest that dietary DAG might induce regression of atherosclerosis.

Various dietary oils are reported to prevent atherosclerosis (14). Fish oils, in particular, help to prevent the progression of atherosclerosis by inhibiting the development of plaques and blood clots at lesion sites (30). These effects are considered to be the result of the multifaceted actions of (n-3) fatty acids [docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA)]. Niot et al. (31) demonstrated that fish oils rich in EPA and DHA lower serum and hepatic lipid concentrations partly because of the activation of fatty acid oxidation in the liver. In addition, Mori et al. (32) reported that EPA ethyl ester improves blood coagulation abnormalities. Thus, certain dietary oils, possibly due to their constituent fatty acids, have beneficial effects on lipid metabolism and thereby on atherosclerosis and CAD. In contrast to previous studies, our results indicate that dietary DAG might be useful for the regression of atherosclerosis compared with TAG, which has a similar fatty acid composition, suggesting that the effects of DAG are related to the acylglycerol structure.

Serum lipid concentrations of normal rabbits were ~0.54 mmol/L (triaclyglycerol) and 0.32 mmol/L (total cholesterol) in a preliminary study. Feeding of a high cholesterol (1.3%) and lard (3%) diet for 50 d markedly increased the serum lipid concentrations. After 34 d of test oil treatment, the serum total cholesterol concentration did not differ significantly between DAG and TAG groups, but serum VLDL triacylglycerol and LDL cholesterol concentrations tended to be lower (P = 0.06–0.1) in rabbits fed DAG than in those fed TAG. In addition, the AI was significantly reduced in DAG-fed rabbits. These results suggest that dietary DAG affects the regression of atherosclerosis through the improvement of postprandial lipoprotein metabolism. DAG might reduce hyperlipemia by activating lipid catabolism in the intestine or in the liver because the postprandial lipoproteins are present mainly as chylomicrons of intestinal origin or VLDL of hepatic origin. In fact, Wong et al. (33) demonstrated that the activation of fatty acid oxidation reduces the production of VLDL in the liver; therefore, the activation of hepatic lipid catabolism might reduce hyperlipemia. Murata et al. (24) reported that dietary DAG reduces FAS activity and elevates the activity of enzymes involved in fatty acid oxidation in the liver of rats. In the present study, dietary DAG decreased the triacylglycerol concentration in the liver. These findings suggest that dietary DAG reduces VLDL production in the liver through the activation of hepatic lipid catabolism, and it follows that the atherogenic processes were thus reduced in DAG-fed rabbits compared with TAG-fed rabbits.

Murase et al. (11) examined the effects of dietary DAG compared with TAG on the development of obesity in mice and demonstrated that DAG prevents obesity and is accompanied by the upregulation of genes involved in lipid metabolism in the small intestine. More recently, Kondo et al. (34) reported the features of 1,3-DAG digestion and assimilation in the intestine and demonstrated that triacylglycerol resynthesis in the intestinal mucosa was more suppressed in DAG-fed rats than in TAG-fed rats. At present, it is unclear whether intestinal lipid

### TABLE 3
Relative mRNA levels in the aortic arch and thoracic aorta in rabbits fed DAG or TAG

<table>
<thead>
<tr>
<th></th>
<th>DAG</th>
<th>TAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic arch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCAM-1</td>
<td>411 ± 11</td>
<td>518 ± 39</td>
</tr>
<tr>
<td>LOX-1</td>
<td>1045 ± 19</td>
<td>1150 ± 80</td>
</tr>
<tr>
<td>Mac-1</td>
<td>2844 ± 32</td>
<td>3088 ± 22</td>
</tr>
<tr>
<td>SR</td>
<td>1881 ± 26</td>
<td>1982 ± 32</td>
</tr>
<tr>
<td>VLDLr</td>
<td>584 ± 9</td>
<td>652 ± 78</td>
</tr>
<tr>
<td>Thoracic aorta</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCAM-1</td>
<td>374 ±10</td>
<td>556 ±118</td>
</tr>
<tr>
<td>LOX-1</td>
<td>2797 ±11</td>
<td>4059 ±167</td>
</tr>
<tr>
<td>Mac-1</td>
<td>671 ±13</td>
<td>1301 ±27</td>
</tr>
<tr>
<td>SR</td>
<td>883 ±19</td>
<td>1300 ±23</td>
</tr>
<tr>
<td>VLDLr</td>
<td>260 ± 46</td>
<td>682 ±166</td>
</tr>
</tbody>
</table>

1 Values are means ± SE, n = 10. *Different from DAG, P < 0.05.
2 Nonatherosclerotic rabbits.

### TABLE 4
Carnitine palmitoyltransferase and fatty acid synthase activities in the liver of rabbits fed DAG or TAG

<table>
<thead>
<tr>
<th></th>
<th>Reference</th>
<th>DAG</th>
<th>TAG</th>
</tr>
</thead>
</table>
| CPT            | 13.2 ± 2  | 16.5 ± 1  | 13.8 ± 0.7*
| FAS            | 14.1 ± 1.5| 6.8 ± 0.9 | 6.7 ± 0.5  |

1 Values are means ± SE, n = 5 (Reference) or n = 10 (DAG and TAG). *Different from DAG, P < 0.05.
2 Nonatherosclerotic rabbits.
metabolism affects the atherogenic processes in rabbits with diet-induced atherosclerosis. The features of DAG digestion and assimilation in the intestine might also affect the regression of atherogenic processes because the suppression of triacylglycerol resynthesis in the intestinal mucosa contributes to reduce hyperlipemia through reduced chylomicron production (35).

Postprandial lipoproteins increase the expression of adhesion molecules such as VCAM-1 and recruit monocytes and/or macrophages to atherosclerotic lesions (36). Furthermore, Hyson et al. (37) reported that postprandial lipemia activates macrophages to atherosclerotic lesions (36). Furthermore, hyperlipemia through reduced chylomicron production (35). resynthesis in the intestinal mucosa contributes to reduce atherogenic processes because the suppression of triacylglycerol assimilation in the intestine might also affect the regression of atherogenic processes. In the present study, DAG tended to reduce VCAM-1 mRNA expression in the thoracic aorta (P < 0.06) and significantly reduced Mac-1 and VLDLr mRNA levels in atherosclerotic lesions. Tada et al. (12) and Mori et al. (13) reported that DAG decreases postprandial serum triacylglycerol and remnant-like lipoprotein levels in humans and animals. In the present study, test fat (DAG or TAG) was orally administered daily; therefore, the DAG-induced suppression of the postprandial lipemia might have been due to repeated administration, which prevented the activation of the endothelial cells and monocytes. These findings suggest that DAG prevents the activation of endothelial cells and monocytes because of its serum lipid-lowering effect and thereby reduces atherogenic processes, including monocyte and/or macrophage infiltration and lipid accumulation in the aorta. Further studies, however, are needed to elucidate the antiatherogenic mechanism of DAG.

In summary, our results indicate that the consumption of DAG might be useful for the regression of atherosclerosis compared with TAG consumption. The anti-atherogenic effect of DAG might be related to the activation of hepatic lipid metabolism and more efficient clearance of postprandial lipids.

**Literature Cited**


