Mechanism for the Cholesterol-Lowering Action of Egg White Protein in Rats

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Eggs are a popular source of dietary cholesterol, but their consumption does not necessarily result in an increased serum cholesterol concentration. We investigated the cholesterol-lowering activity of egg white protein (EWP) and its potential mechanism in rats. The consumption of EWP resulted in a decreased concentration of cholesterol in the serum, liver and intestinal mucosa. The excretion of fecal neutral sterols and bile acids was greater by rats fed with EWP than by those fed with casein. The ratio of cholesterol and bile acids in the micellar phase to those in the solid phase was lower in the intestinal contents from rats fed with EWP than from those fed with casein.

These results suggest that the cholesterol-lowering activity of EWP can be attributed to lowering the cholesterol absorption by intervening in the micellar formation in the intestines.

Key words: egg white protein; cholesterol; intestine; micelle; rat

Hypercholesterolemia is one of the most prevalent risk factors for arteriosclerosis.1) Eggs are cholesterol-containing food; therefore, their consumption is thought to result in an increased serum cholesterol concentration.2) Avoidance of eggs is the usual dietary recommendation to reduce hypercholesterolemia. However, the results of many clinical trials have shown no correlation between egg consumption and the serum cholesterol concentration.3–6) An epidemiological survey has fact in shown a negative correlation between the intake of eggs and cardiovascular diseases.7) Thus, it is thought that a component in egg may help in controlling the serum cholesterol concentration.

It has previously been reported that egg yolk phospholipids lowered the concentration of serum cholesterol by inhibiting cholesterol absorption.8) However, there have been a few studies reporting the effect of egg white on the cholesterol concentration.9–11) Egg white consists mainly of water and protein, but no cholesterol. If egg white protein (EWP) has a cholesterol-lowering effect, it may be of benefit during dietary therapy for hypercholesterolemia. It has been reported that such vegetable proteins as soy protein decreased the serum cholesterol concentration,12–17) whereas such animal proteins as casein increased it.12) Asato et al. have reported that consumption of egg white compared with cheese (milk protein) reduced the serum total- and low-density lipoprotein (LDL)-cholesterol concentrations in humans. The cholesterol-lowering activity of egg white was similar to that of tofu (a processed food made from soy protein).9) Therefore, it is considered that EWP may also reduce the serum cholesterol concentration.

Nagaoka et al. have reported that ovomucin, which is an EWP, inhibited the incorporation of cholesterol into Caco-2 cells by binding to bile acids.11) However, the ovomucin content in EWP is only at the level of 1.5–3.5%.18) Therefore, it is unlikely that the cholesterol-lowering activity of EWP is due to ovomucin alone. EWP is rich in cystine compared with casein. Some workers have reported that cystine supplementation or cystine-enriched protein reduced the serum total cholesterol concentration in rats fed on a high-cholesterol diet.19,20) Others, however, did not confirm the hypocholesterolemic action of cystine, but instead reported the hypercholesterolemic action in rats.21,22) Accordingly, the role of EWP in cholesterol metabolism after egg consumption remains unclear. We showed in this study the hypocholesterolemic action of EWP in rats and propose a possible mechanism that includes the inhibition of cholesterol absorption in the intestines.

Abbreviations: EWP, egg white protein; SD, Sprague Dawley; LDL, low-density lipoprotein; HDL, high-density lipoprotein; AIN, American Institute of Nutrition; ANOVA, analysis of variance

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References:
Material and Methods

**Material.** EWP was prepared from un-sterilized egg white (Q.P. Egg Corporation, Tokyo). The un-sterilized egg white was freeze-dried and crushed uniformly. Casein was purchased from Oriental Yeast Co., Ltd. (Tokyo, Japan). The protein contents, which were determined by the Kjeldahl method, were calculated as the nitrogen content × 6.25. The measured protein content was 84.8% casein and 80.2% EWP. Their cystine content, which was measured by high-performance liquid chromatography, was 2.1% for EWP and 0.4% for casein.

**Animals and diet.** Male SD rats (Japan SLC Inc., Shizuoka) weighing 250–300 g were used in this study. The rats were bred in a temperature (23 ± 1°C) and humidity (50 ± 2%)-controlled room with a 12-h light cycle (light from 08.00 to 20.00). The control diet was formulated according to the AIN-93G formula23 and contained the following ingredients [in weight %]: protein (casein or EWP), 20; α-cornstarch (Oriental Yeast Co., Ltd.), 13.2; sucrose (Mitsui Sugar Co., Ltd., Tokyo, Japan), 10; cellulose (Oriental Yeast Co., Ltd.), 5; mineral mixture (AIN-93, Oriental Yeast Co., Ltd.), 3.5; vitamin mixture (AIN-93G, Oriental Yeast Co., Ltd.), 1; soybean oil (The Nisshin OilliO Group Ltd., Tokyo, Japan), 7; choline bitartrate (Wako Pure Chemical Industries Ltd.) was added at the expense of 0.25; and mineral mixture (AIN-93G, Oriental Yeast Co., Ltd.), 10; cellulose (Oriental Yeast Co., Ltd.), 1; soybean oil (The Nisshin OilliO Group Ltd., Tokyo, Japan), 7; choline bitartrate (Wako Pure Chemical Industries Ltd.) was added at the expense of 0.25; and mineral mixture (AIN-93G, Oriental Yeast Co., Ltd.), 10; cellulose (Oriental Yeast Co., Ltd.), 1; soybean oil (The Nisshin OilliO Group Ltd., Tokyo, Japan), 7; choline bitartrate (Wako Pure Chemical Industries Ltd.) was added at the expense of 0.25; and mineral mixture (AIN-93G, Oriental Yeast Co., Ltd.), 10; cellulose (Oriental Yeast Co., Ltd.), 1; soybean oil (The Nisshin OilliO Group Ltd., Tokyo, Japan), 7; choline bitartrate (Wako Pure Chemical Industries Ltd.) was added at the expense of 0.25; and mineral mixture (AIN-93G, Oriental Yeast Co., Ltd.), 10; cellulose (Oriental Yeast Co., Ltd.), 1; soybean oil (The Nisshin OilliO Group Ltd., Tokyo, Japan), 7; choline bitartrate (Wako Pure Chemical Industries Ltd.) was added at the expense of 0.25; and mineral mixture (AIN-93G, Oriental Yeast Co., Ltd.), 10; cellulose (Oriental Yeast Co., Ltd.), 1; soybean oil (The Nisshin OilliO Group Ltd., Tokyo, Japan), 7; choline bitartrate (Wako Pure Chemical Industries Ltd.) was added at the expense of 0.25, and 0.125% cholic acid (Wako Pure Chemical Industries Ltd.) were added at the expense of β-cornstarch to the high-cholesterol diet containing 20% casein. The cystine content of a casein+cystine diet was equal to that of the high-cholesterol diet containing EWP.

In Experiment 1, the rats were fed daily on the high-cholesterol diet for 3 weeks ad libitum. In Experiment 2, the rats were meal-fed for 2 h (09.00 to 11.00) with the high-cholesterol diet or control diet containing casein or EWP for 3 weeks. In this experiment, the tail vein plasma was collected each week to analyze the changes in cholesterol concentration. The plasma total cholesterol concentration of the rats was influenced by the time when the rats were fed. Therefore, the rats in this experiment were meal-fed to unify the feeding and fasting times. In Experiment 3, the rats were fed with the high-cholesterol diet containing casein or EWP, or with the casein+cystine diet for 3 weeks. EWP contains about 0.5% avidin,18 which inhibits biotin absorption, thereby causing biotin deficiency.24 Avidin consists of a tetramer; thus, 4 mol of biotin could be bound to 1 mol of avidin. The molecular weight of avidin is about 68,000, and of biotin is 244. We calculated the biotin content that could be bound to avidin in the diet containing 20% EWP as 0.0002%. Thus, all the diets in Experiment 3 were supplemented with 0.0002% biotin (Wako Pure Chemical Industries Ltd.) at the expense of β-cornstarch.25 Feces were collected for 3 d just before the end of the feeding period. In Experiment 4, the rats were meal-fed for 1 h (10.00 to 11.00) with the high-cholesterol diet for 1 week, and the small intestine was removed. The intestinal contents were allowed to drain as much as possible into centrifuge tubes by gentle massage. The tubes were placed in a water bath at 70°C for 15 min to deactivate lipase and cholesterol esterase and then centrifuged at 100,000 g for 15 h to obtain two phases: a solid (pellet) phase and a micellar (clear yellowish supernatant) phase.26 The small intestine was washed with ice-cold saline, divided into four equal lengths, and the intestinal mucosa was scraped off.

All rats were freely provided with distilled water throughout the experiments. On the last day, after 8 h of fasting (in Experiment 4, two hours of fasting), the rats were anesthetized with sodium pentobarbital (Dainippon Sumitomo Pharma Co., Ltd., Osaka, Japan), blood was collected from the abdominal aorta, and the liver was removed. The blood was centrifuged at 3,000 g for 10 min to collect the serum. The serum and liver were then stored at −20°C until needed for analysis.

This study was conducted in accordance with the guidelines set for the care and use of laboratory animals by the Ministry of the Environment, Government of Japan.

**Chemical analysis.** The total cholesterol concentrations in the serum from the abdominal aorta and plasma from the tail vein were analyzed with a Cholesterol C-test Wako kit (Wako Pure Chemical Industries Ltd.).27 The serum triglyceride, phospholipid, and high-density lipoprotein (HDL)-cholesterol concentrations were respectively analyzed with Triglyceride C-test Wako, Phospholipid E-test Wako, and HDL-cholesterol C-test Wako kits (Wako Pure Chemical Industries Ltd.).38–40 Hepatic lipids were extracted and analyzed for their cholesterol, triglyceride, and phospholipid concentrations.31–34 The collected feces and solid phase of the intestinal contents were freeze-dried and extracted with ethanol.35 The neutral sterols and bile acid contents of the feces and solid phase were analyzed by gas chromatography, using 5α-cholestane (Sigma-Aldrich Inc., St. Louis, USA) and nor-desoxycholic acid (Toronto Research Chemicals Inc., North York, Canada) as respective internal standards.36,37 The lipids of the intestinal mucosa were extracted, and the
cholesterol content was analyzed by gas chromatography. The cholesterol content of the micellar phase of the intestinal contents was analyzed with a Cholesterol C-test Wako kit (Wako Pure Chemical Industries Ltd.). The bile acid content of the micellar phase was analyzed enzymatically.

**Statistical analysis.** Each result is expressed as the mean ± standard error (SE). The statistical difference between casein and EWP was determined by Student’s t-test, and that between the feeding period and dietary protein was analyzed with a two-way analysis of variance (ANOVA) followed by Dunnett’s test and Student’s t-test. The statistical difference among casein, casein+cystine, and EWP was analyzed with one-way ANOVA followed by Tukey’s test. A p value < 0.05 indicates significant difference. Statistical analyses were conducted with Dr. SPSS for Windows (SPSS Japan Inc., Tokyo, Japan).

**Results**

**Effect of EWP on the serum and hepatic lipid concentrations in rats (Experiment 1)**

SD rats were fed on a high-cholesterol diet containing casein or EWP for 3 weeks ad libitum. No significant differences in body weight gain and food intake were apparent throughout the experiment (Table 1). The serum and hepatic cholesterol concentrations had decreased more after the consumption of EWP than of casein. EWP consumption resulted in a decrease in the hepatic triglyceride concentration. There were no significant differences between the casein and EWP diets in the serum HDL-cholesterol, triglyceride, phospholipid, and hepatic phospholipid concentrations.

**Effects of dietary cholesterol on the cholesterol-lowering activity of EWP (Experiment 2)**

SD rats were meal-fed on a high-cholesterol diet or a cholesterol-free diet containing casein or EWP for 3 weeks (09.00 to 11.00). With the high-cholesterol diet, no significant difference in body weight gain (3.4 ± 0.4 g/d for EWP and 3.2 ± 0.2 g/d for casein consumption) or food intake (15.6 ± 0.5 g/d for EWP and 15.4 ± 0.6 g/d for casein consumption) was apparent. With the cholesterol-free diet, no significant difference in the body weight gain (3.1 ± 0.3 g/d for EWP and 2.6 ± 0.2 g/d for casein consumption) or food intake (14.7 ± 0.8 g/d for EWP and 15.0 ± 0.3 g/d for casein consumption) was apparent. Changes in the plasma cholesterol concentration after EWP and casein consumption with the cholesterol-containing or cholesterol-free diets are shown in Fig. 1. Casein consumption with the high-

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**Table 1. Serum and Hepatic Lipid Concentrations in Rats Fed with a Casein- or EWP-Containing Diet (Experiment 1)**

<table>
<thead>
<tr>
<th>Lipid Type</th>
<th>Casein</th>
<th>EWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth parameter (g/d)</td>
<td>5.22 ± 0.35</td>
<td>5.22 ± 0.47</td>
</tr>
<tr>
<td>Food intake</td>
<td>23.0 ± 0.8</td>
<td>21.9 ± 0.7</td>
</tr>
<tr>
<td>Serum lipids (mg/100 ml)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>122 ± 5</td>
<td>101 ± 7*</td>
</tr>
<tr>
<td>HDL-cholesterol</td>
<td>41.5 ± 3.6</td>
<td>45.9 ± 4.6*</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>194 ± 23</td>
<td>144 ± 19</td>
</tr>
<tr>
<td>Phospholipid</td>
<td>144 ± 11</td>
<td>142 ± 14</td>
</tr>
<tr>
<td>Hepatic lipids (mg/g of liver)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>36.7 ± 2.0</td>
<td>23.3 ± 2.4*</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>109.8 ± 4.8</td>
<td>70.4 ± 5.1</td>
</tr>
<tr>
<td>Phospholipid</td>
<td>29.1 ± 0.9</td>
<td>31.0 ± 0.6*</td>
</tr>
</tbody>
</table>

Mean ± SE of 6 rats.
* p < 0.05 vs. casein group by Student’s t-test.

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**Fig. 1.** Changes in the Plasma Cholesterol Concentrations of Rats Fed with a Casein- or EWP-Containing Diet Supplemented with Cholesterol (A) or without Supplementation (B) (Experiment 2).

- ● Casein group; ○, EWP group. Mean ± SE of 6 rats. * p < 0.05 vs. 0 weeks by Dunnett’s test; # p < 0.05 vs. casein group by Student’s t-test.
Cholesterol-Lowering Action of Egg White Protein

Effect of cystine and biotin on the serum, hepatic, and fecal steroids in rats (Experiment 3)

SD rats were fed on a high-cholesterol diet containing casein, EWP, or casein+cystine for 3 weeks. These three diets were supplemented with 0.0002% biotin. No significant difference in body weight gain or food intake was apparent throughout the experiment (Table 2). The serum cholesterol concentrations were significantly lower after EWP consumption than after casein consumption, but there was no significant effect of dietary cystine. The hepatic cholesterol concentrations were lower after EWP or casein+cystine consumption than after casein consumption. Although the rats were fed with a diet containing 0.0002% biotin in this experiment, EWP still resulted in reduced serum and hepatic cholesterol concentrations. EWP enhanced the serum HDL-cholesterol concentration when compared with the effect from casein. No significant differences were observed in the serum triglyceride, phospholipids, hepatic triglyceride, and phospholipids concentrations. EWP consumption resulted in an increased excretion of fecal neutral sterols and bile acids, but there was no significant effect from dietary cystine.

Effect of EWP on the steroid distribution between the micellar and solid phases of the intestinal contents (Experiment 4)

SD rats were meal-fed a high-cholesterol diet containing casein or EWP for 1 week. No significant difference in body weight gain (2.8 ± 0.5 g/d for EWP and 2.4 ± 0.4 g/d for casein consumption) or food intake (13.8 ± 0.5 g/d for EWP and 14.3 ± 0.9 g/d for casein consumption) was apparent. The serum total cholesterol concentration was significantly lower in the EWP group than casein group (75.6 ± 5.5 mg/100 ml and 102.4 ± 5.8 mg/100 ml serum, p < 0.05). The hepatic cholesterol concentration was also significantly lower in the EWP group than casein group (4.9 ± 0.7 mg/g and 9.5 ± 1.5 mg/g of liver, p < 0.05). No significant difference was apparent in the cholesterol amount in the stomach contents (46.5 ± 1.5 mg for the EWP and 47.7 ± 2.3 mg for the casein group, respectively).

The amount of intestinal contents was significantly higher in the EWP group than in the casein group (Table 3). The micellar volume and solid phase weight were significantly higher in the EWP group than in the casein group (Table 3). In the micellar phase, the cholesterol content was significantly lower in the EWP group than casein group (75.6 ± 5.5 mg/100 ml and 102.4 ± 5.8 mg/100 ml serum, p < 0.05). The hepatic cholesterol concentration was also significantly lower in the EWP group than casein group (4.9 ± 0.7 mg/g and 9.5 ± 1.5 mg/g of liver, p < 0.05). No significant difference was apparent in the bile acid contents between the groups. In the solid phase, the cholesterol and bile acid contents were significantly higher in the EWP group than in the casein group. The ratio of cholesterol or bile acid in the micellar phase to that in the solid phase was significantly lower in the EWP group than in the casein group.

Table 2. Serum and Hepatic Lipid Concentrations, and Fecal Steroid Excretion in Rats Fed with a Casein-, EWP-, or Casein+Cystine-Containing Diet (Experiment 3)

<table>
<thead>
<tr>
<th></th>
<th>Casein</th>
<th>EWP</th>
<th>Casein+cystine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth parameter (g/d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body weight gain</td>
<td>4.89 ± 0.24</td>
<td>5.15 ± 0.26</td>
<td>5.21 ± 0.15</td>
</tr>
<tr>
<td>Food intake</td>
<td>20.5 ± 0.2</td>
<td>19.8 ± 0.4</td>
<td>20.5 ± 0.1</td>
</tr>
<tr>
<td>Serum lipids (mg/100 ml)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>152 ± 11 *</td>
<td>115 ± 5b</td>
<td>136 ± 9b</td>
</tr>
<tr>
<td>HDL-cholesterol</td>
<td>28.6 ± 1.9a</td>
<td>40.6 ± 2.9b</td>
<td>35.3 ± 3.6b</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>130 ± 14</td>
<td>108 ± 15</td>
<td>163 ± 20</td>
</tr>
<tr>
<td>Phospholipid</td>
<td>150 ± 4</td>
<td>156 ± 8</td>
<td>164 ± 9</td>
</tr>
<tr>
<td>Hepatic lipids (mg/g of liver)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>37.8 ± 1.6a</td>
<td>26.2 ± 1.1b</td>
<td>30.0 ± 2.4b</td>
</tr>
<tr>
<td>Triglyceride</td>
<td>81.3 ± 2.5</td>
<td>82.1 ± 5.3</td>
<td>91.2 ± 6.9</td>
</tr>
<tr>
<td>Phospholipid</td>
<td>30.6 ± 1.4</td>
<td>31.2 ± 1.7</td>
<td>29.8 ± 1.7</td>
</tr>
<tr>
<td>Fecal steroids (mg/d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral sterols</td>
<td>43.0 ± 1.4a</td>
<td>49.4 ± 1.0b</td>
<td>39.8 ± 1.3a</td>
</tr>
<tr>
<td>Bile acids</td>
<td>13.9 ± 0.7a</td>
<td>21.4 ± 0.7b</td>
<td>13.7 ± 0.7a</td>
</tr>
</tbody>
</table>

Mean ± SE of 6 rats.

*, Different letters show a significant difference at p < 0.05 by Tukey’s test.

Table 3. Amounts of Cholesterol and Bile Acids in the Micellar Phase and Solid Phase Prepared from the Intestinal Contents of Rats Fed with a Casein- or EWP-Containing Diet (Experiment 4)

<table>
<thead>
<tr>
<th></th>
<th>Casein</th>
<th>EWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intestinal contents</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total weight (g/rat)</td>
<td>1.94 ± 0.19</td>
<td>3.34 ± 0.38*</td>
</tr>
<tr>
<td>Micellar phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total volume (ml/rat)</td>
<td>1.33 ± 0.16</td>
<td>2.42 ± 0.28*</td>
</tr>
<tr>
<td>Cholesterol (mg/rat)</td>
<td>1.27 ± 0.13</td>
<td>0.89 ± 0.09*</td>
</tr>
<tr>
<td>Bile acid (μmol/rat)</td>
<td>109 ± 14</td>
<td>131 ± 10</td>
</tr>
<tr>
<td>Solid phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total weight (mg/rat)</td>
<td>499 ± 32</td>
<td>705 ± 61*</td>
</tr>
<tr>
<td>Cholesterol (mg/rat)</td>
<td>2.64 ± 0.37</td>
<td>4.71 ± 0.46*</td>
</tr>
<tr>
<td>Bile acid (μmol/rat)</td>
<td>33.2 ± 6.2</td>
<td>87.5 ± 12.2*</td>
</tr>
<tr>
<td>Distribution (micellar/solid)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholesterol</td>
<td>0.52 ± 0.06</td>
<td>0.19 ± 0.02*</td>
</tr>
<tr>
<td>Bile acid</td>
<td>4.04 ± 0.92</td>
<td>1.67 ± 0.32*</td>
</tr>
</tbody>
</table>

Mean ± SE of 6 rats.

*, p < 0.05 vs. casein group by Student’s t-test.
No significant difference was apparent for the cholesterol content in the intestinal mucosa is shown in Fig. 2. The cholesterol content of intestinal segment no. 2 was significantly lower in the EWP group than in the casein group. The cholesterol content of intestinal segment no. 2 was higher than in any another segment. No significant difference was apparent in other intestinal segments between the groups.

**Discussion**

The hypocholesterolemic action of EWP has been reported in clinical trials and animal experiments. We confirmed the cholesterol-lowering effect of EWP compared with casein in rats. The cholesterol-lowering action of EWP was observed only for the diet containing cholesterol and bile acid, but not for the cholesterol-free diet. Furthermore, the excretion of fecal neutral sterols and bile acids was significantly higher in the rats fed with the high-cholesterol diet containing EWP than with casein. EWP lowered the hepatic cholesterol concentration. It is therefore likely that EWP reduced the serum cholesterol concentration by inhibiting cholesterol absorption.

A critical step in cholesterol absorption is the efficient incorporation of cholesterol into bile acid micelles from the solid phase in the intestines. In order to address this issue, the intestinal contents were collected 2 h after the diet had been consumed, and the steroid content in the micellar and non-micellar phases (solid phase) was determined. The cholesterol content in the micellar phase was significantly lower in the rats fed with the EWP diet than in those fed with the casein diet. The cholesterol content in the solid phase was significantly higher in the EWP group than in the casein group. Accordingly, the ratio of cholesterol in the micellar phase to that in the solid phase was significantly lower in the EWP group than in the casein group. These results indicate that EWP inhibited the micellar solubility of cholesterol from the solid phase. Furthermore, in this experiment, the amount of intestinal contents was 1.7-fold higher in the EWP group than in the casein group. It is also considered that the lower cholesterol content in intestinal segment no. 2 and the greater excretion of fecal neutral sterol by the EWP group compared with the casein group is attributable to the lower cholesterol absorption in the former group. In the present study, the bile acid content of the solid phase was significantly higher in the EWP group than in the casein group. These results suggest that bile acids derived from bile in the EWP group was not effectively used for the formation of micelles. Furthermore, it remains to be determined if an increased proportion of bile acids in the solid phase might have caused the decreased absorption from the ileum, hence increasing the fecal excretion of bile acids.

A question is here how the EWP diet influenced the partition of cholesterol and bile acids between the micellar and solid phases. It has been reported that ovalbumin constituted about 54% of EWP and was denatured by acidic pH and pepsin. Denatured ovalbumin causes the gelation and formation of hydrophobic particles. Therefore, it is likely that the EWP-derived substances formed during the passage through the digestive tract resulted in the higher amount of intestinal contents in the EWP group than in the casein group, and lowered the proportion of cholesterol and bile acids in the micellar phase.

Furthermore, our preliminary experiment showed that pepsin hydrolysates of ovalbumin (the most abundant component of EWP) and ovotransferrin (the second most abundant component of EWP, about 13%) inhibited the micellar solubility of cholesterol in vitro (Matsuoka, R., unpublished results). Therefore, it is thought that the protein component of EWP was responsible for the lower serum cholesterol concentration by inhibiting the micellar solubility of cholesterol in the intestines. The main component of EWP are 54% ovalbumin, 13% ovotransferrin, 11% ovomucoid, and 3.5% lysozyme. We confirmed that the water-soluble fraction of EWP containing ovalbumin and ovotransferrin pepsin hydrolysates inhibited the micellar solubility of cholesterol, whereas, in soy protein, it has been reported that insoluble fractions such as 7S and 11S globulin had a cholesterol-lowering action. Therefore, it is possible that the cholesterol-lowering mechanism of EWP is different from that of soy protein. In this context, it is interesting to note that ovomucin, which is a less abundant EWP insoluble component (about 1.5–3.5% of EWP), reduced the incorporation of cholesterol into Caco-2 cells by binding to bile acids. In any case,
it is thought that further studies are required to identify the cholesterol-lowering component, including the amino acid composition and the peptides of EWP.

It has been reported that an increased amount of dietary cystine resulted in a reduced serum cholesterol concentration.20) Egg white contains a larger amount of no acid composition and the peptides of EWP. The cholesterol-lowering component, including the amino acid composition (Matsuoka, R., unpublished results). The cholesterol-lowering action of EWP may also be a dose-dependent function.

In summary, the present results indicate the cholesterol-lowering activity of EWP and that the possible mechanism is the reduction of cholesterol absorption by inhibition of the micellar solubility of cholesterol in the intestines.

References


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