Effect of Dietary Fiber on the Lipid Metabolism and Immune Function of Aged Sprague-Dawley Rats

Koji YAMADA,1,† Yoko TOKUNAGA,1 Atsushi IKEDA,1 Ken-ichi OHKURA,1 Shihoko KAKU-OHKURA,1 Soichi MAMIYA,2 Beong Ou LIM,3 and Hirofumi TACHIBANA1

1Division of Applied Biological Chemistry, Department of Bioscience and Biotechnology, Faculty of Agriculture, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan
2Department of Research and Development, Nutritional Foods Division, Taiyo Kagaku Co., Ltd., Yokkaichi 510-0844, Japan
3Department of Medical Nutrition, Graduate School of East-West Medical Science, Kyung Hee University, I Hoegi-Dong, Dongdaemoon-ku, Seoul 130-701, Korea

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Eight-month-old Sprague-Dawley rats were fed on diets containing dietary fiber at the 5% level for 3 weeks to examine the effect on the lipid metabolism and immune function. Among cellulose, guar gum, partially hydrolyzed guar gum (PHGG), glucomannan and highly methoxylated pectin, guar gum induced a significant decrease in the food intake and weight gain, as well as a significant increase in the liver weight. In addition, the epidydimal adipose tissue weight of the rats fed on PHGG was significantly higher than that of the rats fed on cellulose. There was no significant effect on the serum lipid levels, but the serum IgG level of the rats fed on guar gum was significantly lower than that of the rats fed on cellulose. The IgA and IgG productivity in mesenteric lymph node (MLN) lymphocytes was significantly higher in the rats fed on guar gum, glucomannan and pectin than in those fed on cellulose, while the effect on Ig productivity in spleen lymphocytes was not as marked. In addition, only guar gum induced a significant increase of IgM productivity in MLN lymphocytes when compared to the cellulose group. These results suggest that enhancement of the immune function by dietary fiber is mainly expressed in the gut immune system.

Key words: dietary fiber; guar gum; IgA; IgG; mesenteric lymph node

It has been reported that dietary fiber (DF) exerts various physiological effects such as improved serum lipid parameters1,2) and intestinal flora,3–5) prevention of some types of cancers,6) and modulation of immune functions.7,8) Among them, the immunoregulatory effect is related to the incidence or prevention of infectious diseases, allergies and cancers. In addition to DF, immunoregulatory activity has been reported from various food components such as dietary fats and anti-oxidants.9) The application of these biologically active components makes it possible to prevent the occurrence of various diseases.

Among diseases related to immune functions, the prevention of infectious diseases and allergies is important for young people. In this case, stimulation of defensive immunity and suppression of hypersensitivity are essential. In aged people, the regression of defensive immunity is a major problem. Thus, the regulation of immunological activity by food components should be handled age-dependently. However, information on the age-dependency of immune function and responsiveness to food components is limited. We have already reported that some water-soluble DF (WSDF) enhanced serum immunoglobulin (Ig) levels and the Ig productivity of spleen and mesenteric lymph node (MLN) lymphocytes in young Sprague-Dawley (SD) rats.7,8) In the present study, we examined the effect of DF on Ig production in aged rats.

It has also been reported that DF affected the lipid metabolism.1,2) Since fatty acid metabolites such as prostaglandins and leukotrienes exert strong immunoregulatory effects, their effect on lipid metabolism has great meaning for the expression of an immunoregulatory effect, as well as their attribution to the prevention of various diseases related to
liver, heart, lung, kidney, spleen, and epididymal adipose tissue of each rat were immediately excised under diethyl ether anesthesia. The rats were killed by withdrawing blood from the abdominal aorta. The liver, heart, lung, kidney, spleen, and epididymal adipose tissue of the rats that had been fed with DF for 3 weeks, using Lympholyte-rat (Cedarlane, Hornby, Canada), and cultured for 24 hr in an RPMI 1640 medium (Nissui Pharmaceutical, Tokyo, Japan) supplemented with 10% fetal bovine serum (FBS; Intergen, Purchase, NY, U.S.A.) as described previously.10) The IgA, IgG and IgM contents in the serum and culture supernatant were determined by an enzyme-linked immunosorbent assay (ELISA) as described previously.10) The levels of serum cholesterol, triglycerides and phospholipids were enzymatically determined with the commercial kits, Cholesterol Test, TG-G Test and PL-B Test (all from Wako Pure Chemicals, Osaka, Japan). Liver lipid was extracted by the method of Folch et al.,11) and separated into phosphatidylcholine and phosphatidylethanolamine fractions by thin-layer chromatography. The fatty acid composition of the lipid fractions was analyzed with a GC-8A gas chromatograph (Shimadzu, Kyoto, Japan) as described previously.12) Data were analyzed by Duncan’s new multiple-range test13) to determine the exact nature of the differences among groups.

Table 1 shows the dietary effect of DF on the food intake and weight gain of the aged SD rats. The food intake was significantly lower in the guar gum group than in the cellulose and PHGG groups. In the glucomannan and HM-pectin groups, a decreasing tendency was observed in the food intake. In the case of the body weight, there was no increase in the rats fed with guar gum. In addition, the weight gain was less in the PHGG, glucomannan and HM-pectin groups than that in the cellulose group, though the difference was not significant. We have previously observed that both the food intake and weight gain of rats fed on guar gum were smaller than those of rats fed on cellulose in the case of young SD rats,8) although the difference was not significant and there...
was no difference in food efficiency. These results suggest that the effect of guar gum on weight gain appeared more strongly in aged rats than in young rats. In the case of the tissue weight, significant effects were observed on the liver and adipose tissue (Table 1). The liver weight was significantly higher in the rats fed with guar gum than in the rats fed with cellulose. Similarly, an increasing tendency was observed in the rats fed with PHGG, glucomannan, and HM-pectin. In addition, the adipose tissue weight was significantly higher in the rats fed with PHGG than in those fed with cellulose. DF did not affect the weights of these tissues in young rats. 

These results suggest that the effect of DF on the weights of the liver and adipose tissue appeared more strongly in aged rats than in young rats. In addition, a decreasing tendency in the total cholesterol level was observed in the rats fed with guar gum, and glucomannan, and HM-pectin when compared with those fed on cellulose, although the difference was not significant (Table 1). The serum levels of triglycerides and phospholipids in the rats fed with PHGG were higher than in those fed with cellulose, although the difference was not significant. In contrast, significant decreases in the total cholesterol and triglyceride levels were observed in young rats fed with PHGG, guar gum, glucomannan, and HM-pectin, while the phospholipid level was significantly lower in young rats fed with guar gum and glucomannan than in those fed with cellulose. In the case of the serum lipid level, the effect of DF on aged rats was much less than that on young rats. In respect of the fatty acid content in liver phospholipids, DF did not exert as marked effect on aged rats (data not shown) as it did on young rats reported previously. 

The effect on serum Ig levels was that DF exerted a significant effect only on the IgG level (Table 2). The IgG level was significantly lower in the rats fed with guar gum, glucomannan, and HM-pectin than that in the rats fed with cellulose, although the difference was not significant. It has been shown in young rats that serum IgA level was significantly higher in the animals fed with guar gum, glucomannan, and HM-pectin. However, the effect on the serum IgG level was not as marked. These results suggest that the effect of DF on the serum Ig levels was age-dependent. 

A different response for Ig productivity was observed in the spleen and MLN lymphocytes (Table 2). In the case of IgA productivity, there was no significant effect on splenocytes, but it was significantly higher in the rats fed with guar gum, glucomannan, and HM-pectin than in the rats fed with cellulose in MLN lymphocytes. Similarly, a significant increase in IgG productivity was observed only in MLN lymphocytes isolated from those fed with guar gum, glucomannan, and HM-pectin. There was a similar tendency in the IgM productivity, but a significant increase was only observed in the rats fed with guar gum. Enhanced IgA productivity has been observed in both the spleen and MLN lymphocytes of young rats. A significant increase in IgG productivity has also been observed in splenocytes isolated from young rats fed with glucomannan and HM-pectin, as well as in MLN lymphocytes isolated from those fed with these WSDF. In addition, enhanced IgM productivity has been observed in MLN lymphocytes isolated from young rats fed with WSDF. These results suggest that the effect of WSDF on Ig productivity of the lymphocytes appeared more strongly in young rats than in aged rats, as was observed for the effect on lipid metabolism.

WSDF affected more strongly MLN lymphocytes than splenocytes in aged rats. Similarly, dietary conjugated linoleic acid has been reported to enhance the Ig productivity of MLN lymphocytes more strongly than that of spleen lymphocytes. It has
also been reported that dietary α-tocopherol enhanced the Ig productivity of spleen lymphocytes more strongly than that of MLN lymphocytes, while tocotrienols enhanced the Ig productivity of MLN lymphocytes more strongly than that of spleen lymphocytes. These results suggest that various food components affected the Ig productivity of rat lymphocytes in a tissue-specific manner. We have recently found that dietary tocotrienols were predominantly accumulated in MLN and some adipose tissues, while α-tocopherol was more widely distributed in various tissues. Thus, the tissue-specific effect of food components may be due to the transportation of active substances. The enhancement of Ig production in MLN lymphocytes observed here might be useful for enhancing the gut immune system which plays an important role in preventing infectious diseases or the occurrence of allergies.

The oral administration of WSDF induced significant decreases in the serum cholesterol and triglyceride levels, and significant increases in the serum IgA level and IgA productivity of spleen and MLN lymphocytes in 4-week-old young SD rats. We have been shown in the present study that these effects were not induced in 8-month-old aged rats, except for the increase of IgA productivity in MLN lymphocytes. These results suggest that aging affected both the lipid metabolism and immune functions. Osada et al. have reported that the Ig productivity of spleen lymphocytes in 9-month-old aged SD rats was much higher than that of 5-week-old young rats, as well as the intracellular histamine level in peritoneal exudate cells (PEC). However, the histamine-releasing ratio was much smaller in aged rats than in young rats. Mio et al. have asserted that the decrease in the histamine-releasing activity of PEC was due to the reduction of cholesterol content in membrane phospholipids occurring with aging. These results suggest that the change in lipid metabolism accompanying aging is closely related to the change in immune functions.

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References


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