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Rice Bran Oil and Cholesterol Metabolism^{1,2}

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ABSTRACT A range of human and animal studies have shown that rice bran oil (RBO) is an edible oil of preference for improving serum cholesterol levels and lipoprotein profiles with similarity to the more commonly used vegetable oils such as corn oil and safflower oil. Of particular interest is the observation that blending RBO with safflower oil at a definite proportion (7:3, wt/wt) magnifies the hypocholesterolemic efficacy, compared with the effect of each oil alone. Although the mechanism underlying this effect is not apparent at present, the blending may have a practical significance. The blending effect was reproduced in rats fed a cholesterol-enriched diet, and there was also a decrease in liver cholesterol. The occurrence of peculiar components such as γ -oryzanol and tocotrienols could be responsible for the hypocholesterolemic effect of RBO. *J. Nutr.* 127: 521S-524S, 1997.

KEY WORDS: • rice bran oil • cholesterol • γ -oryzanol • humans • rats

Dietary fat is a crucial factor in the regulation of plasma cholesterol levels, and there is overwhelming evidence to support the hypocholesterolemic effect of vegetable oils that are rich in polyunsaturated fatty acids, mainly linoleic acid (Grundy 1994). Rice bran oil (RBO) is not a popular oil worldwide, but it is in steady demand as a so-called "healthy oil" not only in Japan but also in Asian countries, particularly India. Approximately 80 thousand tons of RBO, corresponding to only 3.5% of total vegetable oils, is consumed annually in Japan.

A number of studies in humans and animals have shown that RBO is as effective as other vegetable oils in lowering plasma cholesterol levels (Lichtenstein et al. 1994, Rukmini and Raghuram 1991). In some cases, RBO lowered plasma cholesterol more effectively than other commonly used vegetable oils rich in linoleic acid (Rukmini and Raghuram 1991); this effect can be attributed to the occurrence of specific components in RBO, γ -oryzanol (and its constituents, triterpene alcohols) and perhaps tocotrienols (Nicolosi et al. 1994, Rukmini and Raghuram 1991).

This paper focuses on the hypocholesterolemic effect of RBO in humans and the mechanism underlying the effect.

Fatty acid composition and unsaponifiable material of RBO. The amount of linoleic acid in RBO is rather moderate among the vegetable oils (~40% of total fatty acids), but it is still a rich source. RBO also contains a relatively high pro-

portion of oleic acid (40%). Thus, RBO has a nonspecific fatty acid profile, but it does contain a detectable amount of α -linolenic acid, ranging from 1 to 3% (mean value, 2%). This amount may be enough to increase the content of (n-3) highly polyunsaturated fatty acids such as eicosapentaenoic and docosahexaenoic acids in tissue phospholipids compared with other vegetable oils such as corn oil (Edwards and Radcliff 1994). The remaining major fatty acid in RBO is palmitic acid, 17%.

RBO is characterized by its relatively high content of unsaponifiable material. The content of the unsaponifiable material in refined edible RBO is regulated to be <5% under the Japan Agricultural Standard; this value is considerably higher than that of other vegetable oils, <1-1.5%. The most characteristic component of RBO is γ -oryzanol, the ferulate esters of triterpene alcohols (Table 1) (Itoh et al. 1973a and b). The content of γ -oryzanol differs with the source of RBO, ranging from 115 to 780 ppm, depending on the degree and possibly the method of processing (Rogers et al. 1993). Cycloartenol and 24-methylene cycloartenol are the major component terpenic alcohols, followed by cycloartenol. RBO also contains campesterol and β -sitosterol at a relatively high level. Diverse effects of γ -oryzanol have been reported, including the hypolipidemic effect, growth promotion, gonadotrophic action and stimulation of the hypothalamus (Kanbara et al. 1992, Nakamura 1967, Rukmini and Raghuram 1991).

RBO is also a rich source of tocotrienols, which range from 72 to 612 ppm; this level is comparable to that found in palm oil, which is the good source of tocotrienols (Tan 1989). The major components are β/γ -tocotrienols (Rogers et al. 1993). The content of tocotrienols is usually higher than that of tocopherols. The possible regulatory role of tocotrienols in cholesterol dynamics including hypocholesterolemic action has been reported (Hood and Sidhu 1992, Imaizumi et al. 1990, Qureshi et al. 1991, Watkins et al. 1993).

Effects of rice bran oil on plasma cholesterol concentration. Suzuki and Oshima (1970a and b) studied the effect of

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TABLE 1

Sterol and triterpene contents in different edible oils

Oil	Campesterol	Stigmasterol	β -Sitosterol	Cycloartanol	Cycloartenol	24-Methylene-cycloartanol
	mg/100 g oil					
Rice bran	506	271	885	106	482	494
Safflower	45	31	181	1	34	7
Corn	410	110	1180	4	8	11
Sunflower	31	31	235	—	29	16
Cottonseed	17	4	400	—	10	17
Sesame	117	62	382	4	62	107
Soybean	72	72	191	—	156	8
Peanut	36	21	153	1	11	16

After Itoh et al. 1973a and b.

blending different vegetable oils on serum cholesterol levels of healthy young women. After the RBO was consumed for 7 d, its hypocholesterolemic effect was equal to that of other common vegetable oils such as corn, safflower and sunflower oils. This observation was confirmed recently by Lichtenstein et al. (1994) who compared the effects of RBO, canola and corn oil. However, the most interesting observation by Suzuki and Oshima (1970a and b) was that the blend of 7 parts of RBO with 3 parts of safflower oil unexpectedly enhanced the cholesterol-lowering potential of RBO. As shown in **Figure 1**, the lowering effect of the blended oil was greater than that of the respective oils alone, and other proportions of the blend were less effective in lowering serum cholesterol. Interestingly, the combination of RBO with sunflower oil did not show any additional effects on serum cholesterol levels, although safflower and sunflower oils have essentially the same fatty acid composition. This observation was confirmed repeatedly and the blended oil was commercially distributed.

Further studies by Tsuji and her colleagues (Tsuji et al. 1988 and 1989) observed that the blended oil exerted the hypocholesterolemic effect even when five eggs were consumed daily for 7 consecutive days (**Table 2**). In contrast, there was an increase in HDL-cholesterol after consumption

of the blended oil, and consequently, the atherogenic index was significantly improved. Based on these observations, Tsuji and colleagues later prepared rice bran/safflower oil margarine as a cholesterol-lowering fat.

A recent human study (Raghrum et al. 1989), in which RBO was fed for a longer period, showed a significant hypocholesterolemic effect of this oil compared with other cooking oils. Nicolosi et al. (1991) reported a unique hypocholesterolemic effect of RBO in nonhuman primates that was not attributed to the fatty acid composition of the oil.

The blending effect cannot be explained by the fatty acid composition alone, although a subtle balance of individual fatty acids may play a role. It is in this context that the effect of non-fatty acid component(s) should be considered. Suzuki and Oshima (1970a and b) suggested that the high linoleic acid content of safflower oil, in combination with the micronutrients of the RBO unsaponifiable fraction, acts synergistically to lower the serum cholesterol level. However, this hypothesis does not totally explain the observed effect because blending RBO with sunflower oil was not effective. Thus, it is difficult to attribute the observed blending effect to a single parameter. Although plant sterols appear to exert a combined hypocholesterolemic effect (Ikeda et al. 1985, Kiribuchi et al. 1983), the difference in the sterol composition of safflower and sunflower oils is insufficient to cause such a contrasting effect.

As shown in **Figure 2**, the RBO-safflower oil blend was more effective than safflower oil in lowering plasma and liver cholesterol even in rats fed cholesterol-enriched diets. However, the blending tended to increase slightly the concentration of plasma and liver triglycerides.

Effect of unsaponifiable material on plasma cholesterol concentration. Concerning the possible beneficial effect on

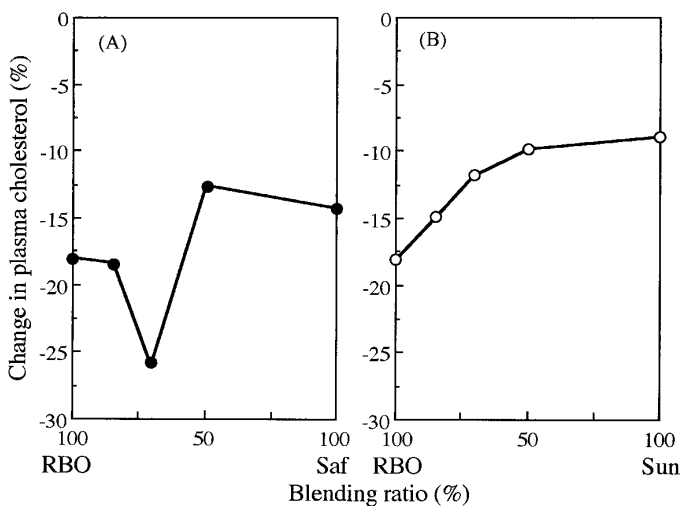


FIGURE 1 Effect of blending rice bran oil with (A) safflower oil and (B) sunflower oil on relative changes in plasma cholesterol levels of young volunteers. Saf, safflower oil; and RBO, rice bran oil. Ten subjects were fed 60 g of the oils daily for 7 d. After Suzuki and Oshima (1970).

TABLE 2

Change of serum lipids after blended oil and egg-loading¹

Serum lipid	Before	After ²
Total cholesterol, mmol/L	3.95 ± 0.53	3.93 ± 0.51
HDL-cholesterol, mmol/L	1.69 ± 0.23	1.94 ± 0.30**
Total/HDL-cholesterol	2.35 ± 0.33	2.05 ± 0.33*
Triglyceride, mmol/L	0.98 ± 0.17	1.02 ± 0.19
Phospholipid, mmol/L	2.48 ± 0.28	2.51 ± 0.30

¹ Mean ± SD of 7 young female volunteers.

² Five eggs and 60 g of blended oil were consumed daily for 7 d.

Significantly different at **P* < 0.05 and ***P* < 0.005.

After Tsuji et al. (1988).

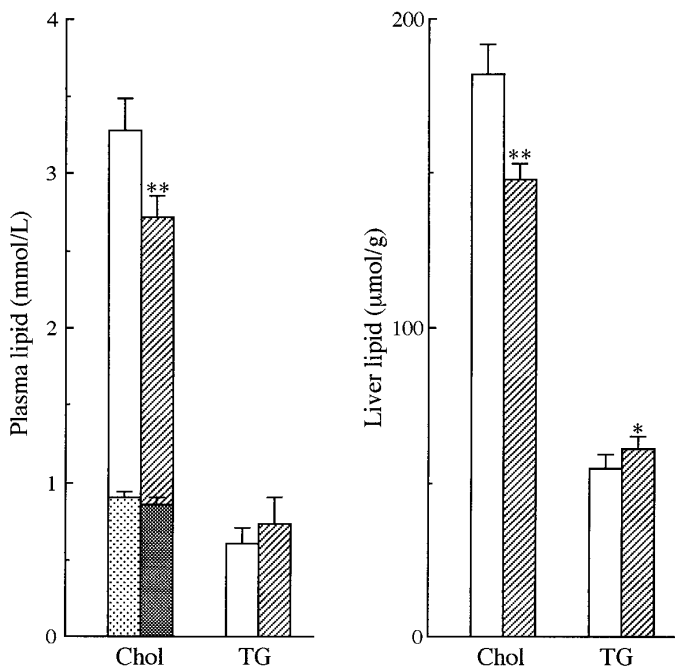


FIGURE 2 Effect of rice bran oil-safflower oil blend on (A) serum and (B) liver lipid levels of rats fed cholesterol-enriched diets. The animals were fed experimental diets containing 10% fat for 3 wk. Values are means \pm SEM of six rats. Chol, cholesterol, and TG, triglyceride. □, Safflower oil group and ▨, rice bran oil-safflower oil blend group (7:3, wt/wt). Dotted bars inside the cholesterol bars represent HDL-cholesterol. Significantly different at * $P < 0.05$ and ** $P < 0.01$.

plasma cholesterol of the unsaponifiable fraction of RBO, Kiribuchi et al. (1983) reported that cycloartenol and probably 24-methylenecycloartanol magnify the cholesterol-lowering potential of soy sterols at a very low dietary level in rats. They attributed the cholesterol-lowering action to increased fecal excretion of acidic steroids. Although this observation was not confirmed in another study (Ikeda et al. 1985), the decrease in serum apo-AI as a result of cholesterol consumption was ameliorated more effectively by the combination of cycloartenol with β -sitosterol than by β -sitosterol alone. In addition,

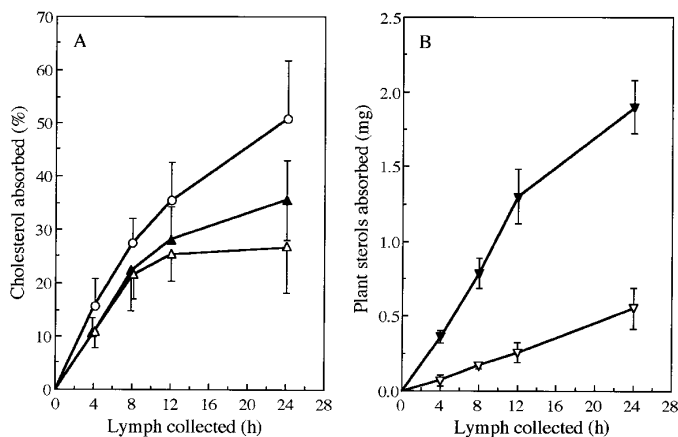


FIGURE 3 Effect of cycloartenol and β -sitosterol on lymphatic cholesterol absorption in rats. Lymph-cannulated rats received emulsions containing (A) 25 mg cholesterol, ○; 25 mg cholesterol and 25 mg β -sitosterol, ▲; or 25 mg cholesterol, 25 mg β -sitosterol and 2.5 mg cycloartenol, △; and (B) 50 mg β -sitosterol, ▽; 50 mg cycloartenol, ▼. Values are means \pm SEM of four rats. After Ikeda et al. (1985).

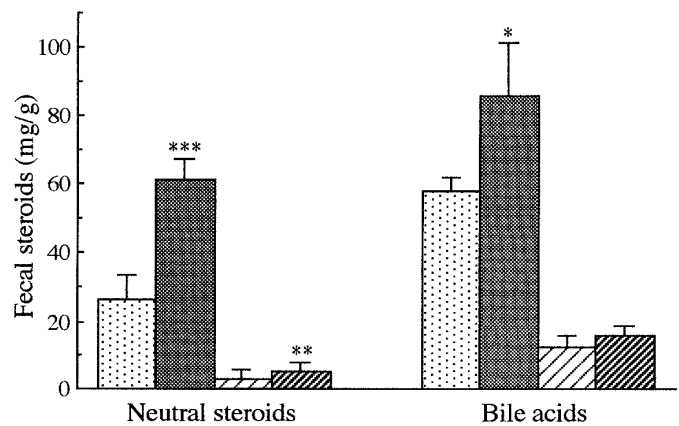


FIGURE 4 Effect of peanut oil and rice bran oil with or without cholesterol on fecal steroid excretion in rats. Values are mean \pm SEM of eight rats. Peanut oil + cholesterol, ▨; rice bran oil + cholesterol, ▩; peanut oil, ▨; rice bran oil, ▩. Significantly different from the corresponding peanut oil groups at * $P < 0.05$, ** $P < 0.01$ and *** $P < 0.001$. After Sharma and Rukmini (1987).

the combination of cycloartenol with β -sitosterol did not reduce the lymphatic absorption of cholesterol as shown in Figure 3. However, cycloartenol was absorbed at a rate ~fourfold higher than that of β -sitosterol, suggesting its metabolic effect after absorption.

Sharma and Rukmini (1986) observed increased fecal excretion of both neutral and acidic steroids in rats fed RBO compared with those fed peanut oil, in particular when cholesterol-enriched diets were given (Figure 4). Further, they showed that the cholesterol-lowering action of peanut oil in rats is magnified by adding a small portion of unsaponifiable material from RBO. The addition of oryzanol to the diet containing RBO led to a further significant decrease in serum cholesterol in rats (Seetharamaiah and Chandrasekhara 1989). In rats fed cholesterol-free diets for 18 wk, RBO reduced plasma and liver cholesterol more than peanut oil at the dietary level of 20% without influencing growth, suggesting that RBO has no deleterious effects, even at a high dietary level.

Although the hypocholesterolemic effect of the blended oil is unusual, it does appear to have practical importance (Tsuiji et al. 1988 and 1989). The hypocholesterolemic effect of the unsaponifiable material can be attributed to the increased fecal steroid excretion through interference with cholesterol absorption (Ikeda et al. 1985, Kiribuchi et al. 1983, Sharma and Rukmini 1986). In addition, the RBO-safflower oil blend ameliorated the age-related increase in blood pressure of spontaneously hypertensive rats when it was added to a commercial nonpurified diet at the 20% level (Tsuiji, E., Kawasaki University of Medical Welfare). It is also known that rice bran itself exerts a cholesterol-lowering action in hamsters (Kahloa et al. 1992).

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