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Cholesterol Supplementation Attenuates the Hypocholesterolemic
Effect of Rice Bran Oil in Rats

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Summary Rice bran oil (RBO), when blended with safflower oil (SFO) at the ratio of 7 to 3, has been shown to lower serum cholesterol in humans consuming cholesterol. The mechanism as to how this oil blend exerts its effect is not yet clear. This study examined the effect of cholesterol supplementation on the cholesterol-lowering ability of different RBO/SFO blends. Male Sprague Dawley rats (4wk old) were fed purified diets containing 10% fat with or without the addition of 0.5% cholesterol for 3wk. The fat was either SFO or RBO alone, or the mixture of these two oils at the ratio of 7:3 (7S/3R), 5:5 (5S/5R), or 3:7 (3S/7R). Without cholesterol supplementation, there were no significant differences in the serum and liver total cholesterol levels among different dietary fats. However, the HDL cholesterol level of rats fed the RBO-containing diets (especially in rats fed the 3S/7R diet) was higher than that of rats fed the diet containing SFO alone. This resulted in an increase in the ratio of HDL/total cholesterol-a desirable outcome. Supplementation of the diets with 0.5% cholesterol significantly increased the cholesterol level in both the serum and the liver. Increasing the proportion of RBO in the diet further raised the total cholesterol level in the serum whereas it reduced liver cholesterol. Then, the specific effect of the 3S/7R mix ture on the ratio of HDL/total cholesterol disappeared. These findings suggest that choles terol supplemented at the level of 0.5% in this study masked the cholesterol-lowering effect of RBO. Smaller percentages of polyunsaturated fatty acid (i.e., 18:2n-6) in the RBO-con taining diets than in the SFO diet might have reduced their ability to dispose the circulating serum cholesterol into the liver.

Key Words rice bran oil, safflower oil, cholesterol, fatty acid profile, rats

Polyunsaturated fats, such as safflower oil (SFO), are known to lower the level of serum cholesterol (1). The effect is attributed to their rich content of linoleic acid

(e.g., up to 80% in SFO). On the other hand, rice bran oil (RBO), in spite of its relative low linoleic acid con tent, has also been shown to lower serum cholesterol level (2,3). The effect of RBO was attributed mainly to its high content of unsaponifiable matters, such as to cotrienols and y-oryzanol (3-5).
In 1970, Suzuki and Oshima was the first group to blend SFO and RBO in different ratios and compare their cholesterol-lowering effects in human volunteers (6,7). They reported that those who consumed the oil blend of RBO and SFO at a ratio of 7:3 for 7d had a

greater reduction in serum cholesterol level than those who consumed either oil alone or oil blends at different ratios. Similar effects have also been observed when a

moderate amount of cholesterol was supplied as eggs (25mg/kg body weight) (8). To date, the mechanism for the cholesterol-lowering effect of SFO and RBO mix ture blended at this particular ratio is still not clear. The objective of the present study was to examine how the supplementation of cholesterol affected the hypocholes terolemic effect of the SFO/RBO blends using a rat

model. Moreover, it is known that dietary cholesterol suppresses the linoleic acid metabolism to arachidonic acid and that the fatty acid profile in liver phospholipid is modified (9-11). Therefore, we also investigated how the oil blends and dietary cholesterol affects the fatty acid profile in liver phospholipids in the present study.

MATERIALS AND METHODS

Animals and Diets. Sixty male weanling Sprague
Dawley rats (4wk old and mean body weight of 82g)
purchased from CLEA Japan, Inc. (Tokyo, Japan), were
acclimatized for 3d in a room maintained at 21-23•Ž
with a 12-h light-dark cycle. Animals were randomly
assigned to 5 different dietary groups. Half of the ani
mals in each dietary group (n=6) received cholesterol
supplementation. The basal diet was made according to
the AIN-93G experimental diet (12) with the exception
that the fat was provided at a 10% level at the expense
of carbohydrates: (by weight %) casein, 20; fat, 10;
cornstarch, 36.7; dextrinized cornstarch, 13.2; su
crose, 10; cellulose, 5.0; mineral mixture (AIN-93G
MX), 3.5; vitamin mixture (AIN-93-VX), 1.0; L-cystine,
0.3; choline bitartrate, 0.25; and t-butylhydroquinone,
0.0014 for cholesterol free diets. The fat was either saf

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Table 1. Fatty acid composition of the five different di etary fats (weight %).

SFO: safflower oil, RBO: rice bran oil, 75/3R: the oil blend of SFO and RBO at the ratio of 7:3, 5S/5R: the oil blend of SFO and RBO at the ratio of 5:5, 3S/7R: the oil blend of SFO and RBO at the ratio of 3:7.

fl ower oil, (SFO, Linol Oil Co., Nagoya, Japan), rice bran
oil (RBO, Fuji Oil Co., Osaka, Japan) or blends of the two
oils at the ratios of 7:3 (7S/3R group), 5:5 (5R/5S
group) and 3:7 (7R/3S group). The fatty acid composi
tion of the five dietary fats is shown in Table 1. For cho
lesterol supplementation, 0.5% cholesterol and 0.125%
sodium cholate were added at the expense of corn
starch. Animals were maintained on their respective
diets ad libitum for approximately 3wk. After 5h-fast
ing, animals were killed by decapitation and blood was
collected into a test tube and allowed to coagulate.
Serum was then separated by centrifugation. The liver
was rapidly excised, rinsed with ice-cold saline, blotted
dry and stored at -80•Ž until analysis.
Lipid Analysis. Serum total and HDL cholesterols
were measured using commercial kits (Cholesterol CII
- test wako, Wako Pure Chemical Industries, Ltd., Osaka,
Japan, and HDL-C•E2 [DAIICHI], Daiichi Pure Chemicals
Co., Ltd., Tokyo, Japan). Total liver lipids were extracted
by the method of Folch et al. (13). The liver phospho
lipid subfractions including phosphatidylcholine (PC)
and phosphatidylethanolamine (PE) were then sepa
rated by thin-layer chromatography developed with a
solvent system of chloroform/ethanol/water/triethy
lamine (4:5:1:5 by vol.). Each lipid fraction was then
transmethylated with BF3-methanol, and its fatty acid
profile was analyzed by gas-liquid chromatography. A
Hewlett-Packard Model 5890 series II plus was used
with an Omegawax 320 capillary column (30m•~0.32
mm, i.d., Supelco, Bellefonte, PA; USA) (14). For liver
cholesterol determination, aliquots of total liver lipid ex
tract were saponified, and cholesterol was extracted
with hexane. The hexane extract of cholesterol was
evaporated to dryness and re-dissolved in ethanol. The
ethanol extract was then analyzed by high-perform
ance liquid chromatography. A Hewlett-Packard 1090
HPLC was used with a Supelcosil LC-18 column
(25cm•~2.1mm, i.d., Supleco). Methanol was used as
the mobile phase at 0.5mL/min. Cholesterol was de
tected at 212nm. A pure standard material of choles
terol (Sigma Chemical Co., St. Louis, MO, USA) was
used to construct a standard curve.
Statistical Analysis. All data were expressed as

Table 2. Effect of safflower oil/rice bran oil mixture on
the body weight gain, food intake and relative liver weight.

All data are expressed as mean•}SD of 6 rats.
ab Values not sharing a common letter are significantly dif
ferent at p<0.05.

mean•}SD of six rats. Data were analyzed by one-way
ANOVA followed by Duncan's multiple-range test to de
termine the dietary fat-dependent differences (15).

RESULTS

Body weight gain and relative liver weight
After 3wk on the cholesterol-free diet, the body
weight gain, food intake and relative liver weight were
greater (but not statistically significant) in rats fed the
RBO-containing diets (7S/3R, 5S/SR, and 3S/7R, and
RBO) than in those fed the SFO diet (Table 2). On the
contrary, when cholesterol was supplemented to the
diets, there was no significant difference among the five
dietary groups.

Serum lipid concentrations
In rats fed the cholesterol-free diet, the serum total cholesterol levels were not significantly different among the dietary groups with the exception of the 7S/3R group, whose serum cholesterol level was higher than that of the other groups (Fig. 1A). The HDL cholesterol levels were generally higher in rats fed the RBO-con taining diets, more so in rats fed the 3S/7R diet, than in those fed the SFO diet (Fig. 1B). As a result, the rats fed the 3S/7R diet had the highest ratio of HDL/total cho lesterol among the five dietary groups (Fig. 1C).
When the diet was supplemented with 0.5% choles terol, the levels of serum total cholesterol were in creased by more than three-fold, whereas the levels of
HDL cholesterol were suppressed significantly. In
creasing the proportion of RBO in the diet further raised the serum total cholesterol level as well as the HDL cho lesterol level. As a result, cholesterol supplementation significantly reduced the ratio of HDL/total cholesterol by four-fold. However, they were not significantly differ ent among the five dietary groups.

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Fig. 1. Effect of safflower oil/rice bran oil mixture on
serum total and HDL cholesterol concentrations and HDL/total cholesterol ratio in rats fed cholesterol-free
(•) and cholesterol-enriched (_??_) diets.
A: serum total cholesterol, B: HDL cholesterol, C:
HDL/total cholesterol ratio.
ab Values not sharing a common letter are significantly
different at p<0.05.

Liver total cholesterol concentration
The effect of different diets on the concentration of

liver cholesterol is shown in Fig. 2. When cholesterol was not included in the diet, the liver cholesterol con centrations were not statistically different among all di etary groups. However, when rats were on the choles terol-supplemented diets, the liver total cholesterol lev els were increased by 10-fold as compared to the choles terol-free diets. Increasing the proportion of RBO in the diet tended to decrease the liver total cholesterol con centration.

Liverphospholipid fatty acids
The fatty acid compositions of the two major liver phospholipid fractions (PC and PE) are shown in Tables 3 and 4.

In rats fed the cholesterol-free diets, the proportions of 18:2n-6 in the liver PC were comparable between different dietary groups. However, when cholesterol was supplemented in the diet, the proportion of 18:2n 6 in the liver PC decreased as the proportion of RBO in the diet increased. The same finding was also seen in the liver PE of rats fed diets with or without cholesterol

Fig. 2. Effect of safflower oil/rice bran oil mixture on
liver cholesterol concentration in rats fed cholesterol
free (•) and cholesterol-enriched (_??_) diets.
ab Values not sharing a common letter are significantly
different at p<0.05.

(Table 4), although the level of 18:2n-6 was generally higher in the liver PC than in liver PE. When rats were given the cholesterol-free diet, the proportion of 20:4n -6 in the liver PC and PE was not affected by the amount of RBO in the diets. Cholesterol supplementation in creased the proportion of 20:4n-6 in the liver PE but decreased that in the liver PC. The supplementation of RBO raised the proportion of 20:4n-6 in both liver PC and PE. In rats fed the cholesterol-free diet, the levels of two 22-carbon polyunsaturated n-6 fatty acids (22:4n -6 and 22:5n-6) in both liver PE and PC were decreased when RBO was included in the diet. Cholesterol supple mentation reduced the level of 22:5n-6 in the liver PC but increased those of 22:4n-6 and 22:5n-6 in the liver PE. However, the cholesterol-induced change was not affected by the level of RBO in the diets. Unlike the two long-chain n-6 fatty acids, the proportions of the long-chain n-3 fatty acids, 22:5n-3 and 22:6n-3, in the liver PC and PE were increased as the proportion of RBO increased in the diets. Cholesterol supplementa tion raised the level of 22:5n-3 and 22:6n-3 in the liver PE, but reduced that of 22:6n-3 in the liver PC. The desaturation index in the liver PC and PE, ex pressed as (20:4n-6+20:3n-6)/18:2n-6, tended to increase as the proportion of RBO increased in the diet. This trend was much more evident in rats fed the cho lesterol-enriched diets than in those fed the cholesterol free diets.

DISCUSSION

In this study, the serum total cholesterol concentra tion of the RBO group was comparable to that of the SFO group and is consistent with that reported by oth ers when compared to corn oil (16,17). This finding suggests that the magnitude of the cholesterol-lowering effect was comparable between RBO and SFO. Suzuki and Oshima have previously reported, in healthy young women, the specific cholesterol-lowering effect of the SFO/RBO blend at a ratio of 3/7 (6,7). Although the ef fect of the oil blend on the serum total cholesterol con centration was less evident, a similar and beneficial of

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Table 3. Effect of safflower oil/rice bran oil mixture on fatty acid profile of the liver phosphatidylcholine (weight %).

All data are expressed as mean•}SD of 6 rats.
DI, desaturation index=(20:3n-6+20:4n-6)/18:2n-6.
abca Values not sharing a common letter are significantly different at p<0
.05.

fect of the 3S/7R blend was observed in the present
study when cholesterol was not included in the diet. We
have observed an increase in serum HDL cholesterol

concentration which is directly related to the propor
tion of RBO in the diet. Additionally, the ratio of HDL/total cholesterol was the highest in rats fed the 3S/7R blend. This finding suggests that the feeding of a cholesterol-free diet supplemented with the 3S/7R blend might be beneficial in reducing the risk of athero screlosis (6, 7, 18, 19).
Tsuji et al, reported that the 3S/7R blend reduced total and LDL cholesterol concentrations in healthy women even when they consumed cholesterol (5 eggs daily for 7d) (8). Their finding suggests that the 3S/7R blend could exert a hypocholesterolemic effect when the intake of cholesterol is approximately 25mg/kg body weight/d in humans. Sugano and Tsuji also de scribed the hypocholesterolemic effect of the 3S/7R blend in rats fed cholesterol-enriched diets (18). Unlike their observation, the cholesterol-lowering effect of the 3S/7R blend was found to be less evident in the present study with cholesterol-supplemented diets. The discrep

ancy in the cholesterol lowering effect between these studies is not clear. In the present study, 0.125% of bile salt was supplemented to a 0.5% cholesterol diet to fa cilitate the absorption of cholesterol. In their study, both cholesterol and bile salt were supplemented, and other ingredients seemed to be similar to those of our study. It has been reported that unsaponifiable matters in RBO reduce serum and liver cholesterol concentration (3-5), but the content of unsaponifiable matter was reported to differ depending on the degree and possibly the method of processing (20). Therefore, the discrepancy might be partly due to the difference in the content of the unsaponifiable matters in RBO between these stud ies. However, this cannot totally explain the discrep ancy. This suggests that the cholesterol-loading effect was somehow less efficient in their study as compared to the present study. The remarkable increase in plasma and liver cholesterol concentrations caused by choles terol feeding was evident in the present study-a 3-fold increase in the concentration of serum total cholesterol and 10-fold increase in the liver cholesterol concentra

tion. Then, the specific effect of the 3S/7R blend on the

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Table 4. Effect of safflower oil/rice bran oil mixture on fatty acid profile of the liver phosphatidylethanolamine (weight %).

All data are expressed as mean•}SD of 6 rats.
DI, desaturation index=(20:3n-6+20:4n-6)/18:2n-6.
abcd Values not sharing a common letter are significantly different at p<0
.05.

ratio of HDL/total cholesterol disappeared. Therefore,
the extent of cholesterol deposition in the liver might
determine the effectiveness of the cholesterol lowering
effect of the 3S/7R diet.
SFO is rich in linoleic acid (•`76%). Dietary supple
mentation with polyunsaturated fatty acids, such as
linoleic acid, has been shown to increase hepatic LDL
- receptor activity, which in turn increases the deposition
of circulating cholesterol into the liver (21,22). On the
other hand, the cholesterol lowering effect of RBO was
attributed, at least in part, to its richness in unsaponifi
able matter (3-5), such as plant sterols (23,24), to
cotrienol (20), and ƒÁ-oryzanol (20). Plant sterols such
as ƒÀ-sitosterol, campesterol and stigmasterol have been

shown to increase the fecal excretion of cholesterol and
bile acids (25), while tocotrienols in RBO inhibit choles
terol synthesis (26-28), and ƒÁ-oryzanol in RBO in
creases the HDL cholesterol concentration (29). In this
study, when rats were fed cholesterol-enriched diets, the
concentration of liver cholesterol decreased signifi
cantly, whereas that of serum total cholesterol in
creased in rats fed the RBO diet as compared to the diet
containing SFO. This resulted in a significant increase

in the ratio of serum/liver cholesterol in rats fed the

RBO-containing diets (Fig. 3). This suggests that both SFO and RBO affected the serum and liver cholesterol concentrations in rats fed cholesterol-enriched diets, and that the choletsteol lowering ability of RBO was not significant. It has been reported that unsaponifiable matters in RBO reduce liver cholesterol concentration

(3-5). Under the cholesterol feeding condition in the present study, the effect of unsaponifiable matter in RBO could also be attributed to the low intake of linoleic acid

in the rats fed RBO-containing diets. Dietary linoleic acid is known to increase the deposition of circulating cholesterol into the liver (21,22). The specific choles terol lowering effect of this oil blend is therefore a result of the combined effect of the linoleic acid in SFO and the

unsaponifiable matter in RBO (30).
It is known that the difference in cholesterol content in the liver affects the metabolism of linoleic acid and

modifies the fatty acid profile of liver phospholipids (9-11). Therefore, it seemed that the difference in liver cholesterol concentration in rats fed the cholesterol-en

riched diet also affected the fatty acid profiles in liver phospholipids. In rats fed the cholesterol-free diets, the

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Fig. 3. Effect of safflower oil/rice bran oil mixture on
serum/liver cholesterol ratio in rats fed cholesterol-free
(•) and cholesterol-enriched (_??_) diets.
Values are calculated as serum cholesterol

(mmol/L)/liver cholesterol (ƒÊmol/g).
ab Values not sharing a common letter are significantly

different at p<0.05.

proportions of 18:2n-6 and 20:4n-6 in the liver PC
were comparable between the five dietary groups.
Cholesterol feeding increased the proportion of 18:2n
- 6, whereas it decreased that of 20:4n-6, indicating the
suppressed conversion of linoleic acid to arachidonic
acid (9-11). However, in the cholesterol-fed rats, feeding
the RBO-containing diets as compared to the SFO diet
decreased the proportion of 18:2n-6 significantly,
whereas it increased that of 20:4n-6 in the liver phos
pholipids. This resulted in an increase in the desatura
tion index, suggesting that the conversion of 18:2n-6
to 20:4n-6 proceeded further in rats fed the RBO diet
than in those fed the SFO diet. The effect could be ex

plained by the observation that the liver cholesterol
concentration was lower in the rats fed RBO diets than
in those fed the diet containing SFO alone, and possibly
a smaller extent of cholesterol-induced inhibition on
liver linoleic acid metabolism occurred under this con
dition. The same effect was also observed in the metabo
lism of ƒ¿-linolenic acid to form long-chain n-3 polyun
saturated fatty acids. For example, the proportion of
22:6n-3, which is a final metabolite of ƒ¿-linolenic acid,
increased significantly in rats fed the RBO diet as com
pared to those fed the diet containing SFO alone. These
results were consistent with those of Edwards and
Radcliffe (17).
In conclusion, the present study confirmed that the
cholesterol-ameliorating effect of RBO blended with
SFO at the ratio of 7/3 in rats fed cholesterol-free diets.
However, when cholesterol was supplemented to the
diets in combination with bile salt, the beneficial effect
of the oil blend was masked. The difference in polyun
saturated fatty acid profiles of dietary fat might have
modulated the deposition of cholesterol from blood to
the liver, and subsequently, a changed liver cholesterol
concentration could modify the fatty acid profiles of the
liver phospholipids.

REFERENCES

1) Horrobin DF, Huang Y-S. 1987. The role of linoleic acid and its metabolites in the lowering plasma cholesterol and the prevention of cardiovascular disease. Int J CardioI 17: 241-255.
2) Rukmini C, Raghuram TCJ. 1991. Nutritional and bio chemical aspects of the hypolipidemic action of rice bran oil: A review J Am ColI Nutr 10: 593-601.
3) Raghuram TC, Rukmini C. 1995. Nutritional signifi cance of rice bran oil. Indian J Med Res 102: 241-244.
4) Seetharamaiah GS, Chandrasekhara N. 1989. Studies on hypocholesterolemic activity of rice bran oil. AtheroscIerosis 78: 219-223.
5) Purushothama S, Raina PL, Hariharan K. 1995. Effect of long term feeding of rice bran oil upon lipids and lipoproteins in rats. Mol Cell Biochem 146: 63-69.
6) Suzuki S, Oshima S.1970. Influence of blending of edi ble fats and oils on human serum cholesterol level (part
11. Eiuoaaku Zasshi 28: 3-6 (in tananese).
7) Suzuki S, Oshima S. 1970. Influence of blending of edi ble fats and oils on human serum cholesterol level (part
2). Eiyogaku Zasshi 28: 194-198 (in Japanese).
8) Tsuji E, Itoh H, Itakura H. 1988. The effects of the veg etable blend oil on the serum LDL and HDL-cholesterol

levels. Proceedings for Nutrition and Atherosclerosis
- Satellite Meeting, 8th International Symposium on Atherosclerosis, p 37-40. CIC Edizoni Internationali, Rome, Italy.
9) Garg ML, Snoswell AM, Sabine JR. 1986. Influence of dietary cholesterol on desaturase enzymes of rat liver microsomes. Prog Lipid Res 25: 639-644.
10) Lee J-H, Ikeda I, Sugano M. 1991. Dietary cholesterol influences on various lipid indices and eicosanoid pro duction in rats fed dietary fat desirable for the protec
tion of ischemic heart disease. J Nutr Sci Vitaminol 37: 389-399.
11) Koba K, Rozee LA, Horrobin DF, Huang Y-S. 1994. Effects of dietary protein and cholesterol on phos phatidylcholine and phosphatidylethanolamine molec
ular species in mouse liver. Lipids 29: 33-39.
12) Reeves PG, Nielsen FH, Fahey GC. 1993. AIN-93 puri fied diets for laboratory rodents: Final report of the American Institute of Nutrition Ad Hoc Writing Committee on the reformulation of the AIN-76A rodent
diet. J Nutr 123: 1939-1951.
13) Folch J, Lees M, Slone-Stanley GH. 1957. A simple method for the isolation and purification of total lipids from aminal tissues. I Biol Chem 226: 497-506.
14) Huang Y-S, Manku MS, Horrobin DF. 1984. The effects of dietary cholesterol on blood and liver polyunsatu
rated fatty acids and on plasma cholesterol in rats fed various types of fatty acid diet. Lipids 19: 664-672.
15) Duncan DB. 1955. Multiple range and multiple F tests. Biometrics 11: 1-42.
16) Lichtenstein AH, Ausman LL, Carrasco W, Gualtieri LJ, Jenner JL, Ordovas JM, Nicolosi RJ, Goldin BR, Schaefer
EJ. 1994. Rice bran oil consumption and plasma lipid levels in moderately hypercholesterolemic humans. Arterioscler Thromb 14: 549-556.
17) Edwards MS, Radcliffe JD. 1994. A comparison of the effect of rice bran oil and corn oil on lipid status in the
rat. Biochem Arch 10: 87-94.
18) Sugano M, Tsuji E. 1997. Rice bran oil and cholesterol metabolism. JNutr 127: 5215-5245.
19) Tsuji E, Itoh H, Itakura H. 1989. Comparison of effects

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of dietary saturated and polyunsaturated fats on the
serum lipids levels. Clin Ter Cardiovasc 8: 149-151.
20) Rogers EJ, Rice SM, Nicolosi RJ, Carpenter DR, MuClelland CA, Romanczyk LJ Jr. 1993. Identification
and quantitation of gamma-oryzanol contents and si
multaneous assessment of tocols in rice bran oil. J Am
Oil Chem Soc 70: 301-307.

21) Spady DK, Dietschy JM. 1985. Dietary saturated tria cylglycerols suppress hepatic low density lipoprotein re ceptor activity in the hamster. Proc Natl Acad Sci USA
82: 4526-4530.
22) Ventura MA, Woollett LA, Spady DK. 1989. Dietary fish oil stimulates hepatic low density lipoprotein transport
in the rat. J Clin Invest 84: 528-537.
23) Itoh T, Tamura T, Matsumoto T. 1973. Sterol composi tion of 19 vegetable oils. J Am Oil Chem Soc 50: 122-125.
24) Itoh T, Tamura T, Matsumoto T. 1973. Methylsterol composition of 19 vegetable oils. J Am Oil Chem Soc 50: 300-303.

25) Ikeda I, Nakashima-Yoshida K, Sugano M. 1985. Effects of cycloartenol on absorption and serum levels
of cholesterol in rats. J Nutr Sci VitaminoI 31: 375-384.

26) Qureshi AA, Burger WC, Peterson DM, Elson CE. 1985. Suppression of cholesterologenesis by plant con stituents: review of Wisconsin Contributions to NC

- 167. Lipids 20: 817-824.
27) Qureshi AA, Burger WC, Peterson DM, Bison CE. 1986 The structure of an inhibitor of cholesterol biosynthesis isolated from barley. J BioI Chem 261: 10544-10550.
28) Qureshi AA, Crenshaw TD, Abuimeileh N, Peterson DM, Elson CE. 1987. Impact of minor plant con stituents on porcine hepatic lipid metabolism. Impact
on serum lipids. Atherosclerosis 64: 109-115.
29) Seetharamaiah GS, Chandrasekhara N. 1990. Effect of oryzanol on cholesterol absorption, biliary & fecal bile acids in rats. Indian J Med Sci 92: 471-475.
30) Sugano M, Tsuji E. 1996. Rice bran oil and human health. Biomed Environ Sci 9: 242-246.