

# Cholesterol-lowering effects of a proprietary Chinese red-yeast-rice dietary supplement<sup>1-4</sup>

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## ABSTRACT

**Background:** We examined the cholesterol-lowering effects of a proprietary Chinese red-yeast-rice supplement in an American population consuming a diet similar to the American Heart Association Step I diet using a double-blind, placebo-controlled, prospectively randomized 12-wk controlled trial at a university research center.

**Objective:** We evaluated the lipid-lowering effects of this red-yeast-rice dietary supplement in US adults separate from effects of diet alone.

**Design:** Eighty-three healthy subjects (46 men and 37 women aged 34–78 y) with hyperlipidemia [total cholesterol, 5.28–8.74 mmol/L (204–338 mg/dL); LDL cholesterol, 3.31–7.16 mmol/L (128–277 mg/dL); triacylglycerol, 0.62–2.78 mmol/L (55–246 mg/dL); and HDL cholesterol 0.78–2.46 mmol/L (30–95 mg/dL)] who were not being treated with lipid-lowering drugs participated. Subjects were treated with red yeast rice (2.4 g/d) or placebo and instructed to consume a diet providing 30% of energy from fat, <10% from saturated fat, and <300 mg cholesterol daily. Main outcome measures were total cholesterol, total triacylglycerol, and HDL and LDL cholesterol measured at weeks 8, 9, 11, and 12.

**Results:** Total cholesterol concentrations decreased significantly between baseline and 8 wk in the red-yeast-rice-treated group compared with the placebo-treated group [ $(\bar{x} \pm \text{SD})$  6.57  $\pm$  0.93 mmol/L (254  $\pm$  36 mg/dL) to 5.38  $\pm$  0.80 mmol/L (208  $\pm$  31 mg/dL);  $P < 0.001$ ]. LDL cholesterol and total triacylglycerol were also reduced with the supplement. HDL cholesterol did not change significantly.

**Conclusions:** Red yeast rice significantly reduces total cholesterol, LDL cholesterol, and total triacylglycerol concentrations compared with placebo and provides a new, novel, food-based approach to lowering cholesterol in the general population. *Am J Clin Nutr* 1999;69:231–6.

**KEY WORDS** Chinese red yeast rice, *Monascus purpureus*, lipid-lowering rice food, HMG-CoA, 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitors, dietary supplement, placebo treatment, low-density-lipoprotein cholesterol, high-density-lipoprotein cholesterol, triacylglycerol

## INTRODUCTION

Red yeast rice is the fermented product of rice on which red yeast (*Monascus purpureus*) has been grown. The use of red yeast rice in China was first documented in the Tang Dynasty in

800 AD. It has been used to make rice wine, as a food preservative for maintaining the color and taste of fish and meat (1), and for its medicinal properties. A complete and detailed description of its manufacture is found in the ancient Chinese pharmacopoeia, *Ben Cao Gang Mu-Dan Shi Bu Yi*, published during the Ming Dynasty (1368–1644) (2). In this text, red yeast rice is characterized as mild and useful for improving blood circulation. In China, consumption of red yeast rice has been studied in animals and humans and has been found to reduce cholesterol concentrations by 11–32% and triacylglycerol concentrations by 12–19% (3–7). Red yeast rice continues to be a dietary staple in many Asian countries, including China and Japan, with typical consumption ranging from 14 to 55 g  $\cdot$  person<sup>-1</sup>  $\cdot$  d<sup>-1</sup> (0.5 to 2 oz) (8). Red yeast rice has also been used in the Asian American community in the United States since World War II. Reducing cholesterol concentrations was shown, in several large prospective clinical trials, to be useful in the primary and secondary prevention of heart disease and the other complications of atherosclerosis (9–12). The current study was conducted to examine the efficacy and safety of red yeast rice in lowering cholesterol concentrations in an American population consuming a diet similar to the American Heart Association Step I diet. A double-blind, prospective, randomized design was used to attempt to separate the effects of the diet from those of the supplement.

## SUBJECTS AND METHODS

This research study was approved by the Institutional Review Board (Human Subject Protection Review Committee) of the

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<sup>2</sup>Supported by an unrestricted educational grant from Pharmanex, Inc, Simi Valley, CA; the University Medical Research Foundation; and the UCLA Clinical Nutrition Research Unit NIH grant no. CA 42710.

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Received February 11, 1998.

Accepted for publication September 11, 1998.

University of California, Los Angeles. Procedures followed were in accord with the ethical standards set forth in the Helsinki Declaration of 1975 as revised in 1983. As required by the Human Subject Protection Review Committee, all subjects were told about possible rare side effects of liver and muscle toxicity observed with cholesterol-lowering drugs. All subjects provided written, informed consent to participate. Patients were randomly assigned to the Chinese red-yeast-rice dietary supplement (Cholestin, Pharmanex, Inc, Simi Valley, CA) and placebo-treated groups.

### Subjects

Subjects were recruited with newspaper advertisements and posted announcements. Seven hundred twenty-eight potential participants were interviewed by telephone in a preliminary screening. Of these, a total of 238 were invited to a screening visit, at which a fasting blood sample was taken for a lipid panel. Subjects with LDL cholesterol >4.14 mmol/L and triacylglycerol concentrations <2.94 mmol/L in a screening sample sent to an outside reference laboratory were entered into the run-in phase. Subjects had not been treated previously for hypercholesterolemia and were required to have normal results for liver and renal function tests at baseline. Subjects taking any lipid-regulating drugs, hormone replacement therapy, immunosuppressive agents, drugs known to affect lipid concentrations, or drugs known to be associated with rhabdomyolysis, including erythromycin and cyclosporine, were excluded from the study. Subjects taking insulin or oral hypoglycemic agents or having an endocrine disease known to lead to lipid abnormalities were also excluded. A total of 83 subjects (46 men and 37 women) completed the trial.

### Methods

Eligible subjects were asked to return for a screening physical examination and repeat fasting blood drawings on 2 occasions. Blood samples were analyzed in the Biomarker Laboratory of the UCLA Center for Human Nutrition. During a 1-wk run-in phase, placebo capsules were provided to assess compliance with pill-taking. Food-frequency questionnaires (FFQs) were completed before randomization, and subjects were provided with an American Heart Association pamphlet entitled *An Eating Plan for Healthy Americans* to instruct them in the Step I diet (<30% of energy from fat, <10% of energy from saturated fat, and <300 mg cholesterol/d). Subjects were then randomly assigned in a double-blind fashion to receive capsules containing either rice powder placebo or 2.4 g red yeast rice daily. Placebo capsules were designed to resemble the dietary supplement as closely as possible. For the treatment group, fermented red yeast rice was pulverized and 600 mg of this milled preparation was encapsulated in each gelatin capsule under Good Manufacturing Practices conditions (Pharmanex, Inc, Simi Valley, CA). The composition of red yeast rice is shown in **Table 1**.

Dietary counseling was provided at the initiation of the study and was standardized so the placebo and treated groups would receive comparable intervention. Body weight was determined by using a calibrated doctor's scale accurate to 0.1 kg. At 8, 9, 11, and 12 wk, fasting blood samples were drawn for lipid assessment. At 12 wk subjects had a second metabolic panel done for assessment of liver and renal function tests. At baseline and at 8 and 12 wk FFQs, developed and validated by Kristal et al (13), were given to assess dietary intake. The FFQ was self-

**TABLE 1**

Composition of Chinese red-yeast-rice dietary supplement

Component	Percentage by wt
	%
Rice starch	73.4
Fiber	0.8
Protein	5.8
Moisture	3–6
Total natural pigment	<0.33
Ash	<3
Phosphorus (organic phosphorus 0.02%)	0.44
Trace elements <sup>2</sup>	Trace
Total HMG-CoA reductase inhibitors	0.4
Monacolin K	0.2
Monacolin K (hydroxy-acid form)	0.1
Dihydromonacolin	<0.01
Monacolin I	0.03
Monacolin II (hydroxy-acid form)	<0.01
Monacolin III	0.02
Monacolin IV	0.02
Monacolin V	0.02
Monacolin VI	0.01
Fatty acids	
Saturated (palmitic and stearic)	<0.5
Mono- and polyunsaturated such as oleic, linoleic, linolenic, and other fatty acids	<1.5

<sup>1</sup>Data are based on unpublished analyses on file with Pharmanex, Inc, Simi Valley, CA. HMG-CoA, 3-hydroxy-3-methylglutaryl coenzyme A.

<sup>2</sup>Calcium, aluminum, iron, manganese, magnesium, copper, and silver.

administered and contained questions about the patients' usual food intake patterns during the 3 mo before the initial and after the last FFQ at 8 and 12 wk.

Plasma cholesterol concentrations were determined by using standard enzymatic methods established in the UCLA Clinical Nutrition Research Unit Biomarker Laboratory (14). Interassay CVs were <4%; intraassay variation was <2%. HDL ( $\alpha$ )-cholesterol concentrations were also determined enzymatically after precipitation of apoprotein B-rich lipoproteins with heparin and manganese chloride (15). LDL-cholesterol concentrations were calculated by using the Friedewald equation (16), which assumes that circulating VLDLs consist of 80% triacylglycerols and 20% cholesterol. The laboratory has participated successfully for 7 y in the Centers for Disease Control and Prevention CDC-NHLBI Lipid Standardization Program (laboratory ID no. LSP 266) meeting all standards of accuracy and precision required by the program.

### Statistical analysis

The statistical design was double-blind and randomized, with 2 treatments and repeated measures. Eighty-eight white subjects were randomly assigned to 2 treatment groups. Lipid and nutrient variables were measured as follows: lipid data were gathered twice at baseline and at 8, 9, 11, and 12 wk. The 2 baseline measurements were averaged, as were the 8- and 9-wk and the 11- and 12-wk data. The FFQs were analyzed based on the data collected at baseline, 8 wk, and 12 wk. The sample size was obtained as follows: the primary variable was total cholesterol and the sample size was based on a two-tailed *t* test with a significance level of 0.05, a power level of 0.90, and with an anticipated effect size  $d = \text{difference of means/standard deviation} = -0.7$ . The required



sample size was 44 in each group for a total of 88. The biostatistical coinvestigators prepared the randomization schedule for the first 80 subjects using the random permuted block design. The remaining 8 subjects were randomly assigned by staff using the schedule of the first 8 of the 80 patients described above. The primary endpoint for total cholesterol was the 12-wk mean of each treatment group.

The baseline means of the study characteristics, both primary and secondary, were compared by 2 independent sample *t* tests (17). Treatment means for each secondary variable were compared separately at 8 and 12 wk by using 2 independent sample Student's *t* tests, except that the variables obtained from the FFQs were compared by using Wilcoxon's rank-sum test (18) because their distributions were nonnormal. Pairwise comparisons for each variable between 8 and 12 wk and baseline were carried out by the paired *t* test or Wilcoxon's signed-rank test (19) for each treatment group. Additionally, differences for each primary variable between 8 wk and baseline were compared between treatment groups. Also, these differences between 12 wk and baseline were compared between treatment groups by using the two-sample *t* test.

Analysis of covariance models (17) were obtained for the lipid variables. The covariance models were carried out separately for the lipid measures at 8 and 12 wk. Terms in the covariance included baseline lipid value, treatment group, sex, age, and initial body weight. In addition, to study the relation between weight and change in lipids, we obtained the correlations between change in weight and change in lipid value using the nonparametric correlation method, Kendall's  $\tau$  (17). A repeated-measures analysis of variance (17) was conducted to compare the time trend curves for each lipid between treatment groups. A *P* value < 0.05 was considered significant.

## RESULTS

### Subject accrual and retention

Eighty-eight patients were enrolled and randomly assigned to the treatment groups. Of the patients assigned, 83 completed the study, 4 subjects discontinued early, and 1 was dropped for protocol violation. One subject withdrew from the red-yeast-rice-treated group and 3 withdrew from the placebo-treated group. Follow-up visits were conducted within 3 d of the target date.

### Baseline characteristics

The important baseline characteristics by treatment are shown in **Tables 2** (lipid variables) and **3** (nutritional and demographic

variables). There were no significant differences in the baseline lipid variables and demographic and dietary variables between the treatment and control groups.

### Primary outcome measures

The total cholesterol concentration decreased significantly between baseline and 8 wk in the red-yeast-rice-treated group compared with the placebo-treated group (*P* < 0.05). Total cholesterol concentrations at 8 and 12 wk differed significantly (*P* < 0.05) between the 2 groups. At 8 wk, the mean total cholesterol concentration was  $5.38 \pm 0.80$  mmol/L ( $208 \pm 31$  mg/dL) in the red-yeast-rice-treated group compared with  $6.57 \pm 0.93$  mmol/L ( $254 \pm 36$  mg/dL) in the placebo-treated group. Furthermore, total cholesterol concentrations at both 8 and 12 wk differed significantly from baseline (*P* < 0.05) in the red-yeast-rice-treated group. At 8 wk, every subject in the red-yeast-rice-treated group experienced a reduction in total cholesterol, whereas there was no significant difference in total cholesterol concentration at 8 and 12 wk compared with baseline in the placebo-treated group. The difference between baseline and 12 wk was  $1.03 \pm 0.54$  mmol/L ( $40 \pm 21$  mg/dL) in the red-yeast-rice-treated group and  $0.13 \pm 0.52$  mmol/L ( $5 \pm 20$  mg/dL) in the placebo-treated group (Table 2).

LDL cholesterol concentrations at 8 and 12 wk differed significantly (*P* < 0.001) between the 2 groups. At 12 wk, the mean LDL-cholesterol concentration in the red-yeast-rice-treated group was  $3.49 \pm 0.70$  mmol/L ( $135 \pm 27$  mg/dL) compared with  $4.53 \pm 0.85$  mmol/L ( $175 \pm 33$  mg/dL) in the placebo-treated group. Furthermore, LDL-cholesterol concentrations at 8 and 12 wk within the red-yeast-rice-treated group differed significantly (*P* < 0.001) from baseline. At 8 wk, all but one of the red-yeast-rice-treated subjects experienced a drop in LDL cholesterol. On the other hand, in the placebo-treated group there was no significant difference between baseline and 8 wk or between baseline and 12 wk. The difference in LDL-cholesterol concentrations in the red-yeast-rice-treated group between baseline and 12 wk was  $1.01 \pm 0.49$  mmol/L ( $39 \pm 19$  mg/dL) compared with  $0.13 \pm 0.57$  mmol/L ( $5 \pm 22$  mg/dL) in the placebo-treated group.

Triacylglycerol concentrations at 8 and 12 wk differed significantly (*P* = 0.05 and *P* = 0.05, respectively) between the 2 groups. At 12 wk, mean triacylglycerol concentrations in the red-yeast-rice-treated group were  $1.4 \pm 0.5$  mmol/L ( $124 \pm 44$  mg/dL) compared with  $1.65 \pm 0.53$  mmol/L ( $146 \pm 47$  mg/dL) in the placebo-treated group. Mean triacylglycerol concentrations within the red-yeast-rice-treated group differed from baseline at 8 wk (*P* = 0.05) but not at 12 wk (*P* = 0.054). On the other hand, in the placebo-treated group there was no significant difference

**TABLE 2**

Lipid concentrations of hyperlipidemic subjects receiving 2.4 g red yeast rice in capsules (treatment) or rice powder placebo (control) supplements daily<sup>1</sup>

	Treatment group (n = 42)			Control group (n = 41)		
	Baseline	Week 8	Week 12	Baseline	Week 8	Week 12
	<i>mmol/L</i>			<i>mmol/L</i>		
Triacylglycerols	1.50 ± 0.54	1.33 ± 0.46 <sup>2,3</sup>	1.40 ± 0.50 <sup>2</sup>	1.61 ± 0.52	1.60 ± 0.59	1.65 ± 0.53
Total cholesterol	6.47 ± 0.78	5.38 ± 0.80 <sup>2,3</sup>	5.43 ± 0.80 <sup>2,3</sup>	6.59 ± 0.75	6.57 ± 0.93	6.47 ± 0.93
HDL cholesterol	1.29 ± 0.34	1.29 ± 0.34	1.29 ± 0.36	1.19 ± 0.26	1.19 ± 0.26	1.19 ± 0.28
LDL cholesterol	4.47 ± 0.70	3.47 ± 0.70 <sup>2,3</sup>	3.49 ± 0.70 <sup>2,3</sup>	4.65 ± 0.78	4.63 ± 0.83	4.53 ± 0.85

<sup>1</sup> $\bar{x} \pm$  SD. Conversion factor to mg/dL for triacylglycerols, 0.01129; for cholesterol, 0.02586.

<sup>2</sup>Significantly different from baseline, *P* < 0.05.

<sup>3</sup>Significantly different from control group at the same week, *P* < 0.05.

**TABLE 3**  
Demographic and dietary characteristics of subjects<sup>1</sup>

	Treatment group (n = 42; 24 M, 18 F)			Control group (n = 41; 22 M, 19 F)		
	Baseline	Week 8	Week 12	Baseline	Week 8	Week 12
<b>Intake</b>						
Total energy (kJ) <sup>2</sup>	6611 ± 2134 (1580 ± 510)	6443 ± 2218 (1540 ± 530)	5607 ± 2050 <sup>3</sup> (1340 ± 490)	7448 ± 3849 (1780 ± 920)	6987 ± 2887 (1670 ± 690)	6694 ± 3012 (1600 ± 720)
Total fat (g/d)	55 ± 26	54 ± 26	44 ± 21 <sup>3,4</sup>	66 ± 46	60 ± 40	59 ± 37
Saturated fat (g/d)	19 ± 10	19 ± 11	15 ± 8 <sup>3</sup>	23 ± 18	20 ± 15	20 ± 14
Monounsaturated fat (g/d)	20 ± 10	20 ± 10	16 ± 8 <sup>3</sup>	24 ± 17	22 ± 15	21 ± 14
Polyunsaturated fat (g/d)	11 ± 5	11 ± 6	9 ± 5 <sup>4</sup>	14 ± 9	13 ± 9	13 ± 8
Cholesterol (mg/d)	202 ± 161	190 ± 116	154 ± 70	241 ± 194	214 ± 146	224 ± 173
Fiber (g/d)	16 ± 6	16 ± 6	15 ± 6 <sup>3</sup>	17 ± 7	17 ± 10	15 ± 8
Weight (kg) <sup>5</sup>	363 ± 73 (165 ± 33)		361 ± 68 (164 ± 31)	370 ± 75 (168 ± 34)		370 ± 75 (168 ± 34)
Body mass index (kg/m <sup>2</sup> )	27 ± 6		27 ± 6	27 ± 5		27 ± 5

<sup>1</sup> $\bar{x}$  ± SD. Age of treatment group, 62 ± 8 y; age of control group, 61 ± 10 y.

<sup>2</sup>Kilocalories in parentheses.

<sup>3</sup>Significantly different from baseline,  $P < 0.05$ .

<sup>4</sup>Significantly different from control group at same week,  $P < 0.05$ .

<sup>5</sup>Pounds in parentheses.

between baseline and 8 wk or baseline and 12 wk. The difference between baseline and 12 wk in the red-yeast-rice-treated group was  $0.10 \pm 0.34$  mmol/L ( $9 \pm 30$  mg/dL) and in the placebo-treated group was  $-0.03 \pm 0.41$  mmol/L ( $-3 \pm 36$  mg/dL).

HDL-cholesterol concentrations did not differ significantly within or between groups at baseline, 8 wk, or 12 wk.

Multiple regression analyses were carried out for each of the 4 lipids measured. In each case, the lipid measurement at 12 wk was the outcome variable. Each regression model examined the effects of baseline lipid, sex, age, treatment group, and initial weight. We obtained the following results. For total cholesterol, baseline total cholesterol and treatment group were significantly correlated with total cholesterol values at 12 wk ( $P < 0.001$  for both). The coefficient for baseline total cholesterol is near 1.0, indicating that the change scores are a valid way of comparing the groups. For triacylglycerol, baseline triacylglycerol and treatment group were significantly correlated with triacylglycerol concentration at 12 wk ( $P < 0.001$  and  $P = 0.05$ , respectively). For LDL cholesterol, baseline LDL and treatment group were significantly correlated with LDL-cholesterol concentration at 12 wk ( $P < 0.001$  for both). A repeated measures analysis of variance showed a significant treatment effect for red yeast rice compared with placebo.

### Nutrition variables

Comparisons within and between study groups at baseline, 8 wk, and 12 wk for total energy, total fat, saturated fat, monounsaturated fat, polyunsaturated fat, and fiber are shown in Table 3. There were no significant differences in dietary intake within or between groups at 8 wk. Blood lipid differences between the red-yeast-rice-treated and placebo-treated groups were already evident at a time (8 wk) when there were no differences in dietary intake. Differences in dietary intake cannot, therefore, account for the observed decrease in cholesterol concentrations. Furthermore, there were no differences in body weight between or within groups at any time. In addition, when using Kendall's  $\tau$  test, there was no significant correlation between changes in weight lipid changes, eliminating weight change as an explanation for the observed changes in lipid concentrations. At 12 wk, the treatment group reported reduced intake of total energy, sat-

urated fat, monounsaturated fat, and fiber compared with baseline, but not when compared with the placebo-treated group. Reported total fat intake and polyunsaturated fat intake were lower than reported at baseline, as well as when compared with the placebo-treated group.

### Safety data

There were no serious adverse effects in any of the 88 subjects randomly assigned. In the placebo-treated group, 3 subjects reported minor adverse effects, including 1) development of a rash that responded to prednisone and antihistamine, 2) headaches, and 3) concurrent development of pneumonia during the study. There were no reported adverse events in the red-yeast-rice-treated group, except for 1 subject who reported an intercurrent hospitalization for musculoskeletal chest pain at his 12-wk visit. He continued taking the dietary supplement while hospitalized and had a normal results for an electrocardiogram stress treadmill test performed by his outside physician. His chest pain resolved and was not related to the dietary supplement.

Liver function indicators at baseline and 12 wk are shown in Table 4. There were no significant differences between treatment groups at baseline or 12 wk. Within groups, urea nitrogen and  $\gamma$ -glutamyltranspeptidase values differed significantly between baseline and 12 wk. Both were lower at 12 wk than at baseline. There were no abnormal liver or renal function test results at any time for any subject under study.

**TABLE 4**  
Liver function indicators of subjects<sup>1</sup>

	Treatment group (n = 42)		Control group (n = 41)	
	Baseline	Week 12	Baseline	Week 12
Alanine aminotransferase (U/L)	22 ± 9	20 ± 8	21 ± 9	21 ± 11
Aspartate aminotransferase (U/L)	24 ± 5	23 ± 6	22 ± 6	22 ± 6
Urea nitrogen (mmol/L)	6 ± 1	5 ± 1 <sup>2</sup>	6 ± 1	6 ± 1
$\gamma$ -Glutamyltranspeptidase (U/L)	27 ± 18	23 ± 19 <sup>2</sup>	23 ± 13	21 ± 11
Lactate dehydrogenase (U/L)	155 ± 25	152 ± 23	158 ± 28	152 ± 19

<sup>1</sup> $\bar{x}$  ± SD.

<sup>2</sup>Significantly different from baseline,  $P < 0.05$ .

## DISCUSSION

In this double-blind, randomized, placebo-controlled prospective study, red yeast rice significantly reduced cholesterol concentrations, beyond effects that could be accounted for by diet alone, and without significant adverse effects. The subjects in this study were instructed in a diet recommended as part of the National Cholesterol Education Program. There are no perfect ways to monitor diet, but the FFQ selected is a validated and accepted tool for this purpose and has been used in other dietary intervention studies (13) and monitors any systematic changes that may have occurred. The usual instructions given to patients are designed to test whether there is a change in cholesterol concentrations with diet alone. Failing this, medications are prescribed to lower cholesterol.

In 1979, Endo (20) discovered that a strain of *Monascus* yeast naturally produced a substance that inhibits cholesterol synthesis, which he named monacolin K (also known as mevinolin and lovastatin), as well as a family of 8 monacolin-related substances with the ability to inhibit 3-hydroxy-3-methylglutaryl coenzyme A (HMG-CoA) reductase. In addition to the inhibitors of HMG-CoA reductase, red yeast rice has been found to contain sterols ( $\beta$ -sitosterol, campesterol, stigmasterol, and sapogenin), isoflavones and isoflavone glycosides, and monounsaturated fatty acids (see Table 1). The quantities of the family of inhibitors of HMG-CoA reductase contained in red yeast rice are inadequate to explain the magnitude of the lowering of cholesterol observed in this study by comparison with evaluations of lovastatin (21). The monacolin K content is only 0.2%, or  $\approx 5$  mg. Therefore, 5 mg is the relevant comparison to 20–40 mg lovastatin. At this concentration, the mixture of monacolins and other substances present in the red yeast rice may have some effect on cholesterol biosynthesis not explained by the monacolin K content. The effect is unlikely to be due solely to a single species of monacolin, but rather to result from a combination of actions of monacolins and other substances in the red yeast rice.


Extensive animal studies of red-yeast-rice extracts have been conducted. In rabbits, one extract (Xuezhikang) lowered cholesterol concentrations by 44% and 59% at doses of 0.4 and 0.8 mg/kg, respectively (3). In an acute toxicity study in mice, there were no toxic effects noted when a single dose of the extract was administered at 533 times the typical human dose (4). Rats were also treated with doses of  $5.0 \text{ g} \cdot \text{kg}^{-1} \cdot \text{d}^{-1}$  for 90 d with no evidence of toxicity on histopathologic examination or in biochemical liver function tests (alanine aminotransferase and aspartate aminotransferase) (5). This corresponds to a dose roughly 50 times that used in humans.

Studies in humans have been conducted in China with both more and less concentrated extracts of the red yeast rice than in our red-yeast-rice-treated group. In 324 hypercholesterolemic subjects treated with Xuezhikang (1.2 g/d containing 13.5 mg total monacolins) for 8 wk, serum cholesterol concentrations decreased by 23%, triacylglycerols decreased by 36.5%, and HDL-cholesterol concentrations increased by 19.6%. Two to 4 wk before the initiation of this study, subjects were instructed to cease taking all medications and were provided with dietary counseling (6). In a second study, an earlier version of the red-yeast-rice supplement containing 10–13 mg total monacolins was given to 101 hypercholesterolemic subjects. Total cholesterol decreased by 19.5% and triacylglycerol decreased by 36.1% in the treated group. HDL-cholesterol concentrations increased by 16.7% in this study (7). These and other Chinese

studies were similar to this study in showing a marked effect of the constituents of this dietary supplement on cholesterol concentrations. However, there were differences in the ethnicity and serum lipid concentrations of the populations studied. Furthermore, a rice placebo was used in the present study in a double-blind fashion, whereas the Chinese studies used different natural preparations in the comparison group rather than a matched placebo capsule.

The benefits of statin drugs on the primary prevention of heart disease (10) and in the secondary prevention of recurrent heart disease (9, 11) have been shown in several large, prospective clinical trials. These studies have increased interest in the use of statins for heart disease prevention, such as for individuals with hypercholesterolemia and modest cholesterol elevations. Although it is acknowledged that side effects with statins are rare and dose related, there are data indicating that some statins may cause liver function abnormalities and, under certain circumstances, rhabdomyolysis (19).

A clinical trial in 5608 men and 997 women with average cholesterol concentrations showed that lovastatin reduced the risk of a first acute major coronary event (22). The authors suggested a “need for reassessment of the national Cholesterol Education Program guidelines regarding pharmacological intervention.” However, an accompanying editorial raised concerns about the economic impact of the use of cholesterol-lowering drugs by the general population with average cholesterol concentrations (23). The currently available Chinese red yeast rice preparation used in the present study costs \$20–30/mo, whereas cholesterol-lowering drugs cost \$120–300/mo, with an average cost of \$187/mo (24). When considering a population-based public health approach to lowering cholesterol and preventing coronary artery disease, the lower cost of the red-yeast-rice dietary supplement compared with prescription drugs could provide a new and novel approach for the maintenance of healthier cholesterol concentrations.

This study was an important first step in establishing that the observed effects of red yeast rice in China were not due to diet alone but could be clearly related to this Chinese red-yeast-rice dietary supplement in a placebo-controlled, randomized trial. This study also established the need for a study on the long-term safety and efficacy of this supplement in a larger population. The effects observed on triacylglycerol concentrations and HDL-cholesterol concentrations in the Chinese studies also need to be examined in future studies by using carefully controlled diets in appropriately selected populations. 

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