Rice Bran: Production, Composition, Functionality and Food Applications, Physiological Benefits

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Production
The world production of rice paddy in 2006 was 631 million metric tons. It resulted in 421 million tons of milled rice, of which 372 million tons were consumed as food. At least 114 countries grow rice and more than 50 have an annual production of 100,000 metric tons or more. The 11 top rice-growing countries are China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, Philippines, Brazil, Japan, and the United States, producing 28.2%, 22.4%, 8.8%, 6.5%, 5.9%, 4.6%, 4.2%, 2.4%, 1.7%, 1.7%, and 1.5% of the world...
rice crop, respectively. The United States contributes 9.5 million metric tons to the annual world rice production. Thailand, Vietnam, the United States, India, Pakistan, and China exported 8.9, 5.9, 4.5, 4.2, 4.2, and 1.2 million tons, respectively: a total of 28.9 million tons of milled rice. Rice, wheat, and corn contribute to 50% of the human caloric intake; rice comprises 23%, wheat 17%, and corn 10% of the calories consumed [1]. Rice is primarily used for human consumption, whereas a larger proportion of wheat and corn are used as animal feed. On average, per capita rice consumption is 56.9 kg per year. Consumption in the developing countries is around 68.5 kg per capita per year, and 12.8 kg per year for developed countries. More than 60% of the calories consumed by the populations of East Asian countries such as Bangladesh, Cambodia, Laos, Myanmar, and Vietnam come from rice. Most rice is consumed as white, milled, polished rice.

Rice as harvested from the field is called paddy. In the rice milling process, first the outermost layer, the hull, is removed to produce brown rice. This process is least damaging to the nutritional value of the rice and avoids the unnecessary loss of nutrients that occurs with the further processing to produce white milled rice. Brown rice would be considered whole grain. One hundred kilograms of paddy on milling yields 56 to 58 kg white rice, 10 to 12 kg broken rice, 18 to 20 kg husk, and 10 to 12 kg rice bran. Rice bran, a by-product of the milling process, contains the enzyme lipase, which rapidly degrades the oil making the bran rancid and inedible. Researchers at the Western Regional Research Center, USDA-ARS, Albany, California, successfully stabilized rice bran by heating it to 125°C–135°C for 1 to 3 seconds at 11% to 15% moisture, and holding the extruded bran at an elevated temperature 97°C–99°C for 3 minutes prior to cooling, thereby deactivating the lipase [2]. Stabilized rice bran (SRB) has an estimated shelf life of about six months and could potentially be used as a food ingredient. Oil can be extracted from the bran and used as a healthful food component.

Each year, 63 to 76 million tons of rice bran (rice milling by-product) is produced in the world and more than 90% of rice bran is sold cheaply as animal feed. The remainder is stabilized and could be used as a value-added health food product. Currently there is some market for SRB as a horse-feed supplement. In the United States, rice oil is being extracted from 15% to 20% of the rice bran.

Parboiling, a steam treatment of paddy, gelatinizes the starch beneath the bran layer of the rice kernel, and yields more white rice, less broken rice, and higher fiber bran. Parboiling stabilizes rice bran by deactivating lipase, but it could destroy the beneficial antioxidants responsible for its health-promoting properties. Steam cooking conditions destroy antioxidants [3]. Antioxidants derived from the diet scavenge and neutralize free radicals, a by-product of metabolism. Free radicals have been implicated in heart disease and cancer.
Composition

The composition of stabilized and parboiled rice bran is given in Table 14.1, and of rice bran oil in Table 14.2. Nutritional studies have identified dietary fiber, bran oil, unsaponifiable matter, sterols, and protein as rice bran’s healthful components. The total dietary fiber (TDF) content of rice bran ranges from 21% to 27%, with less than 2% as soluble dietary fiber (Table 14.1). The protein content of stabilized rice bran ranges from 12% to 16%, and in parboiled rice bran from 14% to 20%. Rice bran protein is efficiently digested and has high nutritional value; it has a protein efficiency ratio of 1.6. Concentrates from
TABLE 14.3
Composition of Rice Bran Oil Unsaponifiable Matter

<table>
<thead>
<tr>
<th>Sterol</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Sterols</td>
<td>43</td>
</tr>
<tr>
<td>Campesterol</td>
<td></td>
</tr>
<tr>
<td>Stigmasterol</td>
<td></td>
</tr>
<tr>
<td>3-Sitosterol</td>
<td></td>
</tr>
<tr>
<td>Triterpene Alcohols</td>
<td>28</td>
</tr>
<tr>
<td>24-Methylene Cycloartenol</td>
<td></td>
</tr>
<tr>
<td>Cycloartenol</td>
<td></td>
</tr>
<tr>
<td>Aliphatic alcohols, hydrocarbons</td>
<td>19</td>
</tr>
<tr>
<td>4-Methyl Sterols</td>
<td>10</td>
</tr>
</tbody>
</table>

Source: [7]

Rice bran protein have an efficiency ratio of 2.0 to 2.2, comparable to casein (2.5), a milk protein [4]. Rice bran contains 22% to 30% crude fat including 1.8% gum and 0.4% wax [5]. The crude fat content of commercial stabilized rice bran is 18% to 22%. The fatty acid composition of rice bran oil consists of 41% monounsaturates, 36% polyunsaturates, and 19% saturates (Table 14.2).

The composition of unsaponifiable matter (UM) in rice bran oil is listed in Table 14.3. Rice bran oil (RBO) contains over 4% of UM, but peanut oil contains only 0.3% to 1% UM [6]. UM is a mixture of 43% plant sterols (campesterol, stigmasterol, β-sitosterol, and others), 28% triterpene alcohols (24-methylene cycloartenol, and cycloartenol), 19% less polar compounds such as aliphatic alcohols and other hydrocarbons, and 10% 4-methyl sterols [7]. Oryzanol, a mixture of ferulic acid esters of triterpenoid alcohols, composes 20% to 30% of UM and 1.1% to 2.6% of bran oil.

Food Applications

Rice bran has many food applications in prepared foods, nutraceuticals, and functional foods. Some of the common applications of rice bran are in snack foods, bakery products, cereals, crackers, pasta products, dough conditioners, beverages, gluten-free foods, and medical foods. The USDA in partnership with a nonprofit organization provides a nutritious rice bran drink to preschool children in the Latin American countries. Rice-bran-containing beverage base can be used for isotonic drinks, iced tea drinks, enhanced juices, mineral supplements, and sports beverages. “Rice Milk” non-dairy alternative to milk is made from organically grown rice. Healthy meal replacement drinks made from stabilized rice bran are being introduced in the market.
Safety

Stabilized rice bran has shown no negative influence on shelf life or organoleptic properties of the various foods when used as an ingredient. Stabilized rice bran has been shown to have no adverse effects on animal health or feed nutritional quality when fed at 60% of the diet in chicks [8, 9] or up to 40% of diet of pigs [10].

Physiological Benefits

Cholesterol Lowering with Rice Bran

Hamster Studies

The hamster has become the preferred rodent model for cholesterol studies, since it has a gall bladder, which is absent in the rat, and the lipoprotein profile of hamster plasma by density gradient ultracentrifugation contains distinct very low-density (20%), low-density (25%), and high-density (55%) lipoprotein fractions. Furthermore, hamsters and humans are reported to be similar in having significant levels of circulating plasma cholesterol and an intrinsically low rate of hepatic cholesterol synthesis, and a similarity in their response to diet modification and drugs [11].

Cholesterol lowering in hamsters by stabilized or parboiled rice bran in the United States was first reported by USDA-ARS (Albany, California) scientists [12] and was acknowledged by a feature article in the Journal of the American Oil Chemists’ Society [13] in which the need was expressed for funding a human study to validate these findings in hamsters. Diets containing 10% TDF from intact full-fat rice bran (stabilized or parboiled) resulted in significantly lower plasma and liver cholesterol compared with the 10% cellulose control diet in hamsters fed 0.5% cholesterol [14]. Replacing one-third of the stabilized rice bran fiber with wheat bran fiber also resulted in significantly lower plasma and liver cholesterol (Table 14.4). In a subsequent study [15], diets containing 10% TDF from stabilized rice bran significantly reduced plasma cholesterol compared to those fed a cellulose control diet, both in the presence and absence of 0.3% cholesterol in the diet. In the cholesterol-fed hamsters, diets containing 11%, 22%, 33%, and 44% rice bran resulted in plasma cholesterol reductions of 8%, 11%, 15%, and 21%, respectively, compared with control values. Plasma cholesterol reductions were significant only with the diet containing 44% rice bran. Although plasma cholesterol reductions were significantly correlated with the level of rice bran in the diet ($r = 0.38$), the low correlation coefficient suggested that the rice bran level alone was a poor predictor of plasma cholesterol lowering.
Several fractions of rice bran were evaluated for cholesterol-lowering properties. Defatted rice bran resulted in a loss of cholesterol-lowering ability [14, 15], suggesting that the lipid fraction was necessary for maximum cholesterol-lowering potential. A combination of defatted rice bran plus RBO or degummed, dewaxed RBO resulted in significant liver cholesterol reductions [5, 15]. However, RBO extracted at 4°C or 54°C and wax and gum fractions of RBO had no significant influence on cholesterol status compared with their respective oil controls [5]. When recombined, it appeared that defatted rice bran and RBO were less effective in lowering cholesterol compared with intact full-fat rice bran, suggesting that either intact RBO was less available or there was a loss/inactivation of cholesterol-lowering activity in the rice oil fractionation process.

Since the liver is the principal organ responsible for the regulation of plasma cholesterol levels, liver cholesterol levels also provide a measure of the influence of diet on cholesterol metabolism. Liver cholesterol was significantly lowered in hamsters by diet containing 10% TDF from rice bran or a 5:5 TDF combination of rice bran and a β-glucan-enriched (19% total β-glucans) barley fraction in diets containing 0.25% cholesterol [16]. In the same study, a diet containing a combination of rice bran and oat bran (5:5, TDF) with 2.6% total β-glucans (0.3% from rice bran, 2.3% from oat bran) resulted in significant plasma and liver cholesterol reductions, suggesting that the contribution of rice bran in lowering cholesterol in hamsters is likely due to components other than β-glucans or soluble fiber (Table 14.4). Measurement of diet slurry viscosities revealed rice bran diet viscosity to be similar to that of the cellulose (insoluble fiber) control diet (<10 cP over a three-hour period), rather than to oat bran diet viscosity (104 cP), indicating that cholesterol lowering
by rice bran is related to a mechanism other than gel forming and sequestering or entrapment of lipid, bile acids, or their metabolites.

In the earlier studies [5, 14, 15] in which either 0.3% or 0.5% cholesterol was fed, rice bran resulted in significant plasma cholesterol reductions, but when dietary cholesterol was lowered to 0.25%, plasma cholesterol was not significantly reduced by the rice bran diet, suggesting that the plasma cholesterol response is dependent on the level of hypercholesterolemia induced in the animals [16].

The source of dietary protein is an additional influence on plasma cholesterol elevations. It is common knowledge that vegetarians have lower plasma cholesterol levels than persons consuming animal protein. In each of the aforementioned hamster studies, the control diets contained casein as the sole source of protein, while treatment diets contained some plant protein. Therefore, a study was designed in which the contribution of plant protein was made equal in all treatments [17]. Diets contained 0.3% cholesterol, 10% TDF, 10.1% fat, and 3% nitrogen with the same plant-to-animal N ratio (44:56), using soy protein and casein in the control diet. Plasma cholesterol was elevated in the control animals to 281 mg/dL, 13% lower than that (322 to 325 mg/dL) observed in previous studies [5, 15] in which hamsters were fed 0.3% cholesterol with casein as the sole source of protein in the control diet. In this study, the unsaponifiable matter (UM) was isolated from rice bran oil and added to cellulose or rice bran diets to provide a total of 0.4% or 0.8% UM in the diets. Probably as a result of the lower level of hypercholesterolemia in the control animals, plasma cholesterol was not significantly lower in animals fed rice bran without added UM but was significantly lower in animals fed stabilized or raw rice bran with 0.4% additional UM from RBO, compared to the control group. Liver cholesterol was significantly lowered by stabilized or raw rice bran with or without added U (0.8% or 0.4% U, respectively), and by cellulose diets with added U (0.8%). Plasma and liver cholesterol reductions were proportional to the amount of UM in the hamster diet. Rice bran diets lowered cholesterol up to twice as much as cellulose diets with equivalent levels of UM. Fecal fat excretion was significantly negatively correlated to liver (r = -0.97) and plasma (r = -0.83) cholesterol values. The results of these hamster studies suggest that UM and other components of rice bran have cholesterol-lowering activity, possibly through increased fecal excretion of lipids.

Kahlon et al. [18] observed a reduction (49% to 65%) in foam cells in the inner bend of the aortic arch in hamsters consuming rice bran diets containing 20% fat and 0.5% cholesterol for six weeks. The size of the plaque area on the inner bend of the aortic arch is a marker for arteriosclerosis and heart disease. Adding a megadose of vitamin E (1000 IU/Kg) resulted in further reduction in the aortic plaque area, but the difference was not significant over animals fed an adequate level (50 IU/kg) of vitamin E. Animals on the rice bran diet excreted more neutral sterols compared to the control animals. Animals consuming megadoses (21 times the normal dosage) of vitamin E with their rice bran diets excreted more neutral sterols than animals receiv-
ing an adequate level of vitamin E. Plant sterols as a major component of these rice bran diets inhibit cholesterol absorption in the intestinal tract and are a proposed mechanism for cholesterol lowering [19].

Rong et al. [20] reported significant reductions in plasma cholesterol (PC), very low density lipoprotein cholesterol (VLDL-C), and low density lipoprotein cholesterol (LDL-C) in hamsters fed 1% oryzanol in diets containing 5% coconut oil and 0.1% cholesterol for seven weeks. Areas of aortic foam cells were reduced (67%) in animals on the oryzanol diet.

Kahlon et al. [21] reported significant reductions in PC, VLDL-C, and liver cholesterol in animals on rice bran diets compared with corn bran or wheat bran diets. Extrusion cooking (processing at two energy levels, 221 and 442 Wh/kg dm) did not change the hypocholesterolemic properties of the rice bran.

Rat Studies

Although the current preference among researchers is to use the hamster model for the evaluation of diet ingredient effects on cholesterol metabolism, earlier work was conducted primarily with the laboratory rat. In cholesterol-fed rats, Ayano et al. [22] reported that the neutral detergent fiber fraction (high in hemicellulose) of rice bran had serum cholesterol-lowering effects, while the acid detergent fiber fraction was ineffective. The hemicellulose fraction was isolated from defatted rice bran and fed to rats at 2% of the diet, resulting in significantly reduced plasma cholesterol (PC) levels (23); however, liver cholesterol was not significantly influenced in either study. Data from the latter investigation suggested that the hypocholesterolemic effect of rice bran hemicellulose involved increased excretion of bile acid, but not liver accumulation of cholesterol or suppression of cholesterol absorption. Others reported no significant PC reductions with diet containing 10% stabilized rice bran from parboiled rice compared to 10% cellulose or fiber-free control diets fed to rats for four weeks [24]; however, none of the diets contained added cholesterol and the level of rice bran in the diet was low. When diets containing 1% cholesterol, 0.2% cholic acid, 10% TDF from raw or parboiled rice bran, and 17% to 19% fat were fed to rats for 21 days, both plasma and liver cholesterol levels were significantly reduced by the rice bran diets compared with the fiber-free control diet [25]. Topping et al. [26] found significantly lower plasma and liver cholesterol in rats fed cholesterol-free diets containing 7% TDF from heat-stabilized rice bran compared to 7% TDF from unprocessed wheat bran. The cholesterol reductions were related to increase in hepatic low-density lipoprotein (LDL) receptor activity. Supplementing 5% fish oil in the diet achieved further reductions in PC.

Cholesterol-lowering effects of rice bran oil and rice bran oil UM were reported in rats fed 1% cholesterol and 0.5% cholic acid diets for eight weeks [27]. Results showed that either 10% RBO or 0.4% rice bran oil UM significantly lowered PC and liver cholesterol compared to peanut oil. In another study with cholesterol-fed rats, significantly lower PC, LDL-C, and VLDL-C were observed with 10% RBO compared with those fed peanut oil [28]. An
addition of 0.5% oryzanol to RBO diet showed a further significant decrease in PC. Rice bran oil also lowered liver cholesterol and triglycerides significantly. Evidence of a possible mechanism for the hypocholesterolemic activity of oryzanol was reported in a subsequent study in which a significant increase in fecal cholesterol and bile acid excretion and a 20% reduction in cholesterol absorption in vitro were observed after rats were fed 0.5% oryzanol and 1% cholesterol diet [29]. An additional mechanism for reducing atherosclerotic risk with oryzanol was suggested by significantly lower ADP-induced platelet aggregation and total inhibition of aggregation by collagen when 0.5% oryzanol was added to 1% cholesterol rat diet [30].

Other components of rice bran reported to have cholesterol-lowering activity in rats include wax isolated from RBO, which significantly lowered plasma and liver cholesterol and increased fecal fat excretion when fed at 10% of the diet [31], and rice bran protein, which significantly lowered serum cholesterol compared to casein or fish protein in rats fed cholesterol-free diet [32]. The hypocholesterolemic effect of rice protein was attributed to the higher arginine/lysine ratio in rice protein relative to animal protein.

Morita et al. [33] reported significant serum cholesterol reduction in rats fed a rice protein diet compared with those fed a casein diet. Sunitha et al. [34] observed significant reduction in PC, LDL-C, and liver cholesterol in rats fed rice bran oil plus safflower/sunflower oil in a 70:30 ratio for four weeks. The fecal neutral sterols and bile acid content increased in animals on a diet containing rice bran oil.

**Other Species**

Rabbits fed 20% rice protein diet had significantly lower PC, VLDL-C, and LDL-C compared to those fed casein [35]. In addition to the higher arginine/lysine ratio of rice protein compared to that of casein (1.13 vs. 0.44), the authors also suggested that the lower percentage of acetate-generating amino acids (valine, leucine, isoleucine, phenylalanine, tryptophan, and lysine) in rice protein versus casein (33.49% vs. 38.17%, respectively) may have been partly responsible for the cholesterol-lowering effects.

In male cynomolgus monkeys, rice bran oil significantly lowered PC and LDL-C without affecting high density lipoprotein cholesterol (HDL-C) compared with a diet containing a mixture of butter oil, com oil, and olive oil in an eight-week feeding study [36]. In contrast, feeding a 50% rice bran diet to female cynomolgus monkeys fed increasing amounts of cholesterol for 9 months resulted in no PC reductions [37]. A stabilized rice bran diet with 7% TDF significantly lowered PC but not liver cholesterol in C57BL/6 mice compared to a fiber-free control diet when diets contained 0.06% cholesterol from ground beef [38].

In chicks fed a diet containing 0.5% cholesterol, 60% full-fat rice bran, and 24% fat, PC and LDL-C were significantly lowered while HDL-C was significantly increased, compared with the 7% fat control diet; however, when diets were made isocaloric (10.8% fat), LDL-C significantly increased and HDL-C
TABLE 14.5
Human Studies: Plasma Cholesterol Lowering by Rice Bran (RB) and Rice Bran Oil (RBO)

<table>
<thead>
<tr>
<th>Treatment Duration</th>
<th>Control</th>
<th>Treatment</th>
<th>Effect</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 days (100g RB)</td>
<td>235</td>
<td>211</td>
<td>Significant</td>
<td>43</td>
</tr>
<tr>
<td>21 days (100g RB)</td>
<td>217</td>
<td>208</td>
<td>Not significant</td>
<td>43</td>
</tr>
<tr>
<td>15 days (RBO)</td>
<td>247</td>
<td>204</td>
<td>Significant</td>
<td>49</td>
</tr>
<tr>
<td>30 days (RBO)</td>
<td>247</td>
<td>183</td>
<td>Significant</td>
<td>49</td>
</tr>
<tr>
<td>4 weeks (60g RB)</td>
<td>245</td>
<td>242</td>
<td>Not significant</td>
<td>42</td>
</tr>
<tr>
<td>21 days (15g RB)</td>
<td>176</td>
<td>172</td>
<td>Not significant</td>
<td>46</td>
</tr>
<tr>
<td>21 days (30g RB)</td>
<td>176</td>
<td>169</td>
<td>Not significant</td>
<td>46</td>
</tr>
<tr>
<td>42 days (84g RB)</td>
<td>267</td>
<td>245</td>
<td>Significant</td>
<td>44</td>
</tr>
</tbody>
</table>

Plasma Cholesterol, mg/dL

increased with no effect on PC [39]. Defatted rice bran increased PC, LDL-C, and HDL-C, suggesting that PC-lowering properties of rice bran in chicks may be associated with rice bran oil.

Human Studies

Unpolished rice showed a repressive effect on serum cholesterol and triglyceride elevations in adult males compared with those fed polished rice; the beneficial effect was attributed to the dietary fiber of the unpolished rice [40]. Five healthy young men consumed brown rice with 27.9 g of neutral detergent fiber (NDF) per day for 14 days, resulting in significant increases in fecal wet weight, dry weight, water, and fat excretion compared with those fed white rice with 13.7 g of NDF per day [41]. PC and HDL-C levels were not significantly different from those with a polished rice diet, possibly due to the fact that total cholesterol concentrations in the subjects were in the lower part of the normal range. In a four-week study, 24 mildly hypercholesterolemic men consuming 60 g/d of rice bran diet containing 11.8 g dietary fiber, had 4% (nonsignificant) reductions in LDL-C and apo-B, significant increases in their HDL-C/PC ratio, and no change in PC compared to those consuming wheat bran [42] (Table 14.5). It was concluded that a consumption of realistic amounts of a single food source of dietary fiber could provide a modest benefit to the antiatherogenic profile of plasma lipoproteins. In a three-week crossover design study, significant reductions in PC and LDL-C were observed in 11 subjects with moderately elevated blood cholesterol after consuming 100 g/d of rice bran or oat bran [43]. Reductions were 10% (significant) during the first three weeks and 5% (nonsignificant) during the second three-week period, with an overall reduction of 7% (Table 14.5). Cholesterol reductions with rice bran and oat bran were similar. In a six-week non-crossover design study [44], moderately hypercholesterolemic adults achieved significant reductions in serum total and LDL cholesterol by consuming 84 g/d
of heat-stabilized, full-fat medium grain rice bran product or oat bran. The bran supplements were added to the subjects' usual daily intake of a low-fat, low-cholesterol diet and did not replace any dietary components. There were no significant differences between the serum cholesterol reductions with the rice bran product (8.3%) versus those with the oat bran (13.0%).

Addition of a mixture of 30 g each of rice bran and oat bran to the daily diets of 17 moderately hypercholesterolemic and hypertriglyceridemic individuals for six weeks resulted in no significant reductions in TC or HDL cholesterol [45]. The authors suggested that the level of dietary fiber tested may have been inadequate or that increasing soluble fiber intake may not be the sole answer to reduce hyperlipidemia. Consuming 15 or 30 g/d of rice bran by 18 normocholesterolemic subjects for three weeks resulted in no significant changes in TC, LDL cholesterol, or HDL cholesterol, although triglycerides (a risk factor) were significantly reduced with 15 g/d rice bran consumption compared with 15 g/d wheat bran [46]. Again, the normocholesterolemic state of the subjects may have been partly responsible for the lack of effect on TC and LDL-C and HDL-C.

A 60 g mixture of rice bran oil and safflower oil (70:30) given for seven days to 10 females per group was more effective in lowering TC than either of the oils alone [47, 48]; most of the subjects had normocholesterolemic basal levels at the start of each treatment. Other investigators also reported a beneficial effect when customary cooking oil was replaced with rice bran oil for 15 and 30 days, resulting in significant reductions in TC and triglycerides in 12 hypercholesterolemic and hypertriglyceridemic subjects [49] (Table 14.5). Significant cholesterol-lowering effects of γ-oryzanol were reported in hyperlipidemic patients who were given 300 mg/d γ-oryzanol for three months [50]. Consuming a diet supplemented with 35.5 g/d of full-fat rice bran for 18 days significantly lowered serum cholesterol in 10 subjects, compared to a fiber-free control period, whereas 30 g/d of defatted rice bran was not effective [51], suggesting that cholesterol reductions were due to the lipid component of rice bran.

Hypercholesterolemic human subjects showed the same cholesterol-lowering effect as the animal model when fed cereal fiber, rice bran, and oat bran diets. In experiments conducted over 15 and 30 days, Raghuram et al. [49] reported a reduction in TC among 12 hypercholesterolemic men, who replaced their normal diet of peanut cooking oil with rice bran oil (Table 14.5). However, there were no reductions in total cholesterol in normocholesterolemic men who ate 15 or 30 grams of dietary fiber per day [46]. Hypercholesterolemic subjects who consumed the NCEP step-1 diet and a tocotrienol-rich extract of rice bran oil significantly reduced TC and LDL-C [52]. Hypercholesterolemic individuals who consumed rice bran oil or the tocotrienol-rich fraction from rice bran oil reduced TC and LDL-C [53, 54]. Numerous and exhaustive human and animal studies have shown that stabilized rice bran, rice bran oil, and tocotrienol-rich fraction of rice oil lower TC, LDL-C, and improve the HDL/TC ratio.
Bile Acid Binding by Rice Bran

Binding bile acids and increasing their fecal excretion has been linked with cholesterol lowering in plasma and liver [55–57]. In vitro bile acid binding by stabilized rice bran on dry matter basis has been observed to be 12% to 25% of that by cholestyramine (a bile acid binding drug) [58, 59].

Whole Grain Recommendation

USDA's new food guide (2005) recommends consuming 50% of grains as whole rather than refined. The healthful potential of rice bran has been documented by various in vitro, animal and human studies. It would be advisable to consume brown rice as whole grain rice rather than fortifying milled white rice with stabilized rice bran. Brown rice takes 45 minutes to cook as compared with 20 minutes for white rice. Process technologies need to be perfected to reduce cooking time for brown rice and consumers need to receive the information that brown rice is a preferred food. Instant brown rice, partially cooked brown rice, or rice flour blasted brown rice to facilitate water penetration are in the works at various research facilities to reduce the cooking time for brown rice and to facilitate its consumer acceptance.

Market Potential

Currently only a small fraction of the rice bran produced worldwide is stabilized and sold as health food. Rice bran and its fractions are sold at different price levels depending upon the final use or application. The wholesale price for stabilized rice bran ranges from $2.92 to $4.25 per Kg. Retail prices vary from $6.14 to $58.64 per Kg (Table 14.6). If all the rice bran and rice oil produced were sold as health food, the price would lower to encourage consumer preference. The stabilized rice bran at $1 per Kg would have a potential market value of $63 to $76 billion per year (world production = 63 to 76 million tons). It would be utilized as a food ingredient and its full healthful potential could be realized.

Summary

Animal and human studies show cholesterol lowering with rice bran in hypercholesterolemic individuals, with reductions occurring usually in the
TABLE 14.6
Stabilized Rice Bran Prices

<table>
<thead>
<tr>
<th>Source</th>
<th>$/Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wholesale</strong></td>
<td></td>
</tr>
<tr>
<td>Rice Bran (spot price)</td>
<td>2.92</td>
</tr>
<tr>
<td>Rice Bran Deoiled</td>
<td>4.25</td>
</tr>
<tr>
<td><strong>Retail</strong></td>
<td></td>
</tr>
<tr>
<td>Health Foods Markets</td>
<td></td>
</tr>
<tr>
<td>Rice Bran Organic</td>
<td>9:50</td>
</tr>
<tr>
<td>Rice Bran Solubles</td>
<td>87.89</td>
</tr>
<tr>
<td>Rice Bran</td>
<td>6.14</td>
</tr>
<tr>
<td>Rice Bran Syrup</td>
<td>27.48</td>
</tr>
<tr>
<td>Rice Bran (low fiber)</td>
<td>55.01</td>
</tr>
<tr>
<td>Rice Bran (with fiber)</td>
<td>58.64</td>
</tr>
<tr>
<td>Rice Bran (with fiber)</td>
<td>49.50</td>
</tr>
<tr>
<td>Rice Bran Beverage</td>
<td>102.65</td>
</tr>
<tr>
<td>Rice Bran Oil</td>
<td>4.45-15.38</td>
</tr>
</tbody>
</table>

Notes: 63–76 million tons/year, $63–76 billion potential value per year.

LDL (atherogenic) fraction. Specific rice bran fractions showing hypocholesterolemic activity include rice bran oil, unsaponifiable matter, dietary fiber, and protein. There is a dose response to the level of rice bran and rice bran oil unsaponifiable matter for cholesterol reductions, but intact full-fat rice bran appears to be the most effective. This suggests that incorporation of intact stabilized rice bran into food products would be more effective than the fortification of food with isolated individual concentrated fractions of rice bran. Consuming brown rice as whole grain would be highly desirable.

Possible mechanisms for cholesterol lowering with rice bran include interference with absorption/reabsorption of dietary and/or endogenous lipid in the gastrointestinal tract and increased excretion of bile acids, which results in utilization of more cholesterol for bile acid synthesis. In addition, changes in hepatic LDL receptor activity have been reported with rice bran feeding [18], and the inhibition of cholesterol synthesis by tocols and tocotrienols present in rice bran oil may also contribute to cholesterol reduction [42]. The evidence to date suggests that several mechanisms may be simultaneously involved in the cholesterol-lowering effects of rice bran.

Atherosclerosis is a disease that apparently takes from 40 to 50 years to develop. The concept of a 2% reduction in risk with each 1% reduction in cholesterol in high-risk individuals is well accepted. With reported plasma total and LDL cholesterol reductions of 4% to 10% in subjects with moderate hypercholesterolemia, the available information suggests that inclusion of rice bran in the diet, along with a reduction of fat calories to 30% and satu-
rated fat to less than one-third of total fat, could prove to be healthful for the general population. Commercial interest generated by the health effects of rice bran has contributed to the introduction of numerous value-added rice-bran-containing foods and food products such as breads, breakfast cereals, cakes, cookies, extruded snacks, muffins, pies, and snack bars. The popularity of the new rice bran products is encouraging and expected to continue with health-conscious consumers. Incentives are needed for the rice industry to increase the production and availability of stabilized rice bran for its incorporation into more healthful, value-added foods for human consumption.

References


Rice Bran