Iron absorption from brown rice/brown rice-based meal and milled rice/milled rice-based meal

TRINIDAD P. TRINIDAD1, AIDA C. MALLILLIN1, ROSARIO S. SAGUM1, DAVE P. BRIONES1, ROSARIO R. ENCABO1 & BIENVENIDO O. JULIANO2

1Food and Nutrition Research Institute, Department of Science and Technology, Bicutan, Taguig, Metro Manila, Philippines, and 2Philippine Rice Research Institute Los Baños, College, Laguna, Philippines

Abstract
Background Milled rice is the staple food among Filipinos and is mostly consumed three times a day. Rice as a source of iron could therefore have an important role in the existing 37% prevalence of iron-deficiency anemia in the country. Previous iron absorption studies in Filipinos from rice and rice-based meals were carried out on milled rice but no research was done on brown rice of the same variety. This leads to the hypothesis that brown rice may be better than milled rice in terms of iron content.

Objective To determine iron absorption from brown rice and brown rice-based meal, and from milled rice and milled rice-based meal of the same variety.

Methods The rice variety used in the study was F2 seeds of PSB Rc72H. Iron absorption from brown/milled rice and brown/milled rice-based meals was determined in 12 healthy human subjects from the incorporation of radioisotopes of iron into erythrocytes 14 days after administration of the labeled rice/rice-based meals. The above samples were also analyzed for nutrient content, including dietary fiber, and iron.

Results The iron content of brown rice was significantly higher (1.1 ± 0.1 mg/100 g) than that of milled rice (0.6 ± 0.1 mg/100 g). Brown rice has significantly greater amounts of total dietary fiber (5.4 ± 0.4%) than milled rice (1.7 ± 0.2%; P<0.05). Both tannic acid and phytic acid contents in brown rice (56.9 ± 3.2 mg/100 g and 290.1 ± 18.0 mg/100 g, respectively) were significantly higher than those of milled rice (21.3 ± 2.3 mg/100 g and 84.0 ± 12.4 mg/100 g, respectively; P<0.05). The amount of iron absorbed from brown rice (0.13 ± 0.02 mg) did not differ significantly from that from milled rice (0.14 ± 0.02 mg). However, the amount from brown rice-based meal (0.36 ± 0.04 mg) differed significantly from that from brown rice (P<0.05) as well as that from milled rice-based meal (0.35 ± 0.03 mg) from that from milled rice (P<0.05). Moreover, brown rice-based meal did not differ significantly from milled rice-based meal (P<0.05).

Conclusion Iron absorbed from milled rice and brown rice did not differ significantly, as well as that from brown rice-based meal and milled rice-based meal. Differences in iron absorbed from brown/milled rice and brown/milled rice-based meals may be due to the iron content of the test foods and the presence of iron enhancers in the meal (e.g. fish, vegetables and citrus fruit).

Keywords: Iron absorption, brown rice, milled rice
Introduction

Iron-deficiency anemia is prevalent in most developing countries, like the Philippines. According to the recent 2003 national nutrition survey conducted by the Food and Nutrition Research Institute, Department of Science and Technology, 37 out of 100 Filipinos are anemic (Food and Nutrition Research Institute 2006). Rice is the staple food of most Filipinos. It contains 200–300 mg/100 g phytic acid but was not found to inhibit iron absorption especially in the presence of meat, fish or poultry and the ascorbic acid present in fruits and vegetables in Filipino meals (Trinidad et al, 1986, 1989). However, it was found that rice-based meal containing 3,000 mg/100 g tannic acid or greater inhibited iron absorption in regional meals in the Philippines (Trinidad et al. 1986). Previous iron absorption studies in Filipinos from rice and rice-based meals were carried out on milled rice but no research was done on brown rice of the same variety. This leads to the hypothesis that brown rice may be better than milled rice in terms of iron content and absorption.

The Asia Rice Foundation with the Philippine Rice Research Institute (PhilRice) launched a brown rice popularization drive in 2001, based on nutritional considerations: a higher content of vitamins and minerals, despite poorer acceptability and shelf-life, as compared with milled rice. Studies on iron absorption from brown rice are scarce. Brown rice has been shown to have greater iron availability in vitro than milled rice but lower zinc and calcium availability (Feliciano 2001). However, in vitro digestion and ferritin formation in cultured human intestinal Caco-2 cells of cooked rice digests showed higher iron absorption (ferritin formed) on milling of five brown rice varieties (Prom-u-Thai et al. 2006). Studies conducted in Thailand on milled and brown rice revealed that the percentage iron absorption from milled rice was greater than that of brown rice (Tuntowiroon et al. 1990; Sirichakwal et al. 2006). However, because of the higher iron content of brown rice, the absolute amount of iron absorbed from the milled rice can be lower than brown rice (Sirichakwal et al. 2006). Brown rice, in comparison with milled rice, contains more dietary fiber in addition to phytic and tannic acids (Miyoshi et al. 1986, 1987). Dietary fiber has been shown to interfere with mineral absorption in the small intestine. Nevertheless, if the fiber is fermentable in the colon it can release the mineral for absorption in the colon (Thompson et al. 1991; Trinidad et al. [1996a],[b]). The objective of the present study is to determine the absorption of iron from brown rice/brown rice-based meal and milled rice/milled rice-based meal of the same variety in humans.

Materials and methods

Test foods

Brown rice (PSB Rc72H), milled rice (PSB Rc72H), Hasa-hasa (Rastrelliger brachyosomus), kangkong (Ipomoea batatas aquatica), and kalamansi (Citrus microcarpa) were used as the test foods in the study. Rough rice (F₂) from the 2002 dry season crop of PhilRice was decupled in a Satake THU 35 type dehuller and one-half of the brown rice was milled in a Satake One-Pass table-type SKD mill DCK L2 at 9.3% reduction of 100-grain weight. One hundred grams of brown rice was soaked in 350 ml distilled water for 30 min and boiled in an individual aluminum pot for each subject. Similarly, 100 g milled rice was cooked without soaking in 300 ml distilled water. The amount of water used for brown rice and milled rice differed because
brown rice needed more water to cook. The other ingredients were purchased from the Bicutan, Taguig Market and were cooked separately from the rice, as described by Trinidad et al. (2002). A different portion of the cooked meal was homogenized and freeze-dried for analysis.

Subjects

All subjects were male, aged 24–39 years, with a body mass index of 24.4 ± 1.0 kg/m² and in the normal range of hemoglobin (15.0 ± 0.2 g/dL) and hematocrit (51.5 ± 1.8%).

Analytical methods

Cooked and freeze-dried brown rice/brown rice-based meal and milled rice/milled rice-based meal of the same variety were analyzed for iron (Association of Official Analytical Chemists [1995a]), non-heme iron (Torrance and Bothwell 1968), phytic acid (Association of Official Analytical Chemists 1986), tannic acid (Earp et al. 1981), dietary fiber (e.g. total, soluble and insoluble) (Association of Official Analytical Chemists [1995b]) and proximate analysis (Association of Official Analytical Chemists 2000).

Protocol of the study

After an overnight fast, blood was drawn from the subjects for baseline data. The subjects were randomly fed with meal A consisting of brown rice extrinsically labeled with 0.5 μCi/subject ⁵⁹Fe (Perkin Elmer, Boston, MA, USA) and with meal B consisting of brown rice extrinsically labeled with 1.0 μCi/subject ⁵⁵Fe (Perkin Elmer), fish and vegetables, on two consecutive days in the order AB. After 14 days, blood was drawn from each subject for radioactivity measurements. Subjects were randomly fed again with milled rice labeled with 0.5 μCi/subject ⁵⁹Fe (meal C) and with labeled milled rice (1.0 μCi/subject ⁵⁵Fe), fish and vegetables (meal D), on two consecutive days in the order CD. After 14 days, blood was drawn and a reference dose of labeled iron (0.5 μCi/subject ⁵⁹Fe), consisting of ferrous sulfate and ascorbic acid was administered to each subject. After 14 days, blood was drawn again from each subject. Blood samples were read in a liquid scintillation counter after digestion using the modified method of Eakins and Brown (1966). No food or drink was taken by the subjects until 4 h after ingestion of the labeled food for all treatments. The protocol of the study was cleared by the Food and Nutrition Research Institute Human Ethics Committee.

Statistical analysis

Because the distribution of iron absorption data is positively skewed when expressed as a percentage of the administered dose, the data were transformed to logarithms and results reconverted to an anti-logarithm to recover the original units. Differences in iron absorption between treatments and subjects were determined by repeated-measures analysis of variance and Duncan’s multiple range tests using the SAS Program (Statistical Analysis System, Cary, NC, USA).


Results

Results were expressed as the mean ± standard error of the mean. Table I presents the nutrient analysis and iron content of rice samples tested. Brown rice had significantly higher ash, fat and iron content than milled rice while moisture and carbohydrate content were significantly higher in milled rice (P<0.05). Brown rice had significantly greater amounts of total and insoluble dietary fiber than its respective milled rice (Table I; P<0.05). Milled rice did not contain soluble dietary fiber. The tannic acid content of brown rice (56.9 ± 3.2 mg/100 g) and milled rice (21.3 ± 2.3 mg/100 g) was below 100 mg, suggesting that brown rice and milled rice are not good sources of tannic acid. On the other hand, brown rice had significantly greater phytic acid (290.1 ± 18.0 mg/100 g) content than milled rice (84.0 ± 12.4 mg/100 g; P<0.05). Brown rice-based meal had significantly greater tannic acid and phytic acid contents (198.7 ± 0.88 mg/100 g and 317.4 ± 0.96 mg/100 g, respectively) than milled rice-based meal (165.2 ± 0.81 mg/100 g and 140.1 ± 0.16 mg/100 g, respectively).

The iron absorption from rice samples and meals is shown in Table II. The percentage iron absorption was higher from milled rice than from brown rice. However, the absolute amount of iron absorbed from rice samples revealed that brown rice did not significantly differ from milled rice (Table II; P<0.05, n=12). Iron absorbed from brown/milled rice-based meal was significantly higher than that of brown/milled rice (P<0.05). This showed that iron absorbed from rice-based meals was increased by their higher iron content and in the presence of iron enhancers (e.g. fish, vegetables and citrus fruit juice). The heme iron content of fish (total iron – non-heme iron; Table II) given per subject was 0.2 mg. The vegetable (kangkong) used in the study contained 30 mg ascorbic acid/100 g, and kalamansi juice, a citrus fruit added to the vegetable used in the study, contained 45 mg ascorbic acid/100 g (Food and Nutrition Research Institute 1997). The total intake of ascorbic acid per subject from kangkong (44 g) and kalamansi (10 g) was 17.7 mg.

Discussion

Iron absorption studies from brown rice are scarce. Studies performed in Thailand revealed a greater percentage iron absorption from milled rice than from brown rice (Tuntowiroon et al. 1990; Prom-u-Thai et al. 2006); however, because of the high

Table I. Nutrient content and total iron of cooked and freeze-dried brown and milled rice.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Brown rice</th>
<th>Milled rice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (g/100 g)</td>
<td>5.3 ± 0.1b</td>
<td>6.0 ± 0.1a</td>
</tr>
<tr>
<td>Ash (g/100 g)</td>
<td>1.3 ± 0.0a</td>
<td>0.2 ± 0.0b</td>
</tr>
<tr>
<td>Fat (g/100 g)</td>
<td>2.5 ± 0.0a</td>
<td>1.1 ± 0.1b</td>
</tr>
<tr>
<td>Protein (g/100 g)</td>
<td>6.1 ± 0.2a</td>
<td>5.9 ± 0.0a</td>
</tr>
<tr>
<td>Carbohydrates (g/100 g)</td>
<td>84.8 ± 0.3b</td>
<td>86.8 ± 0.2a</td>
</tr>
<tr>
<td>Dietary fiber (g/100 g)</td>
<td>4.6 ± 0.2a</td>
<td>1.7 ± 0.1b</td>
</tr>
<tr>
<td>Insoluble fiber (g/100 g)</td>
<td>3.6 ± 0.1a</td>
<td>1.7 ± 0.1b</td>
</tr>
<tr>
<td>Soluble fiber (g/100 g)</td>
<td>1.0 ± 0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Iron (mg/100 g)</td>
<td>1.1 ± 0.1a</td>
<td>0.6 ± 0.1b</td>
</tr>
</tbody>
</table>

Data presented is expressed as mean ± standard error of the mean n=4. Data in the same row with different superscript letters denote significant differences at P<0.05.
Iron content of brown rice, iron absorbed from brown rice showed no significant differences with that of milled rice (Sirichakwal et al. 2006). This study revealed similar results to those of Thailand. Iron absorbed from brown rice and milled rice of the same variety as well as their respective rice-based meals did not differ significantly, despite the lower percentage iron absorption from brown rice. This was also attributed to the significantly higher iron content of brown rice than its respective milled rice (Table II; \( P < 0.05 \)). The significant increase in iron absorbed from brown rice/milled rice-based meals than brown rice/milled rice alone may be due to the presence of heme iron from fish, and ascorbic acid in vegetables and citrus fruit juice. Heme iron is readily and well absorbed and it also promotes the absorption of non-heme iron present in a meal (Lynch and Stoltzfus 2003). The quantitative recommendation for ascorbic acid effect on iron absorption was based on an ascorbic acid to iron molar ratio between 2.1 and 4.1 (Lynch and Stoltzfus 2003). The ascorbic acid to iron molar ratio from our study showed 1.5:1 for brown rice-based meal and 2:1 for milled rice-based meal. The vegetable in the meal was steamed, suggesting less or no loss of ascorbic acid. The citrus fruit juice was given raw. On the other hand, Filipino meals contained 200–300 mg/100 g phytic acid but were not found to inhibit iron absorption especially in the presence of meat, fish or poultry and of ascorbic acid present in fruits and vegetables (Trinidad et al. 1986, 1989). Also, rice-based meal with less than 3,000 mg/100 g tannic acid did not inhibit iron absorption in regional meals in the Philippines (Trinidad et al. 1989). Brown rice, in comparison with milled rice, contains significantly greater dietary fiber (Table I) in addition to phytic and tannic acids. Dietary fiber has been shown to interfere with mineral absorption in the small intestine. Nevertheless, if the fiber is fermentable in the colon it can release the mineral for absorption in the colon (Thompson et al. 1991; Trinidad et al. [1996a],[b]). Results showed that the dietary fiber, phytic acid and tannic acid from brown rice did not interfere with iron absorption.

In conclusion, the iron absorbed from brown rice and milled rice of the same variety did not differ significantly, as well as that from the respective meals. There was a significant increase in iron absorbed when both brown rice and milled rice were served with fish, vegetables and citrus fruit juice.

**Acknowledgements**

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<table>
<thead>
<tr>
<th>Test food</th>
<th>Food intake (g)</th>
<th>Total iron per intake (mg)</th>
<th>Non-heme iron per intake (mg)</th>
<th>Iron absorption (%)</th>
<th>Iron absorbed (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown rice</td>
<td>228.9 ± 3.4b</td>
<td>2.51 ± 0.02c</td>
<td>2.31 ± 0.02c</td>
<td>5.5 ± 1.2c</td>
<td>0.13 ± 0.02b</td>
</tr>
<tr>
<td>Brown rice-based meal</td>
<td>322.9 ± 5.2a</td>
<td>3.81 ± 0.01a</td>
<td>3.61 ± 0.01a</td>
<td>9.9 ± 2.2b</td>
<td>0.36 ± 0.04a</td>
</tr>
<tr>
<td>Milled rice</td>
<td>221.4 ± 5.0b</td>
<td>1.33 ± 0.01d</td>
<td>1.33 ± 0.01d</td>
<td>10.3 ± 2.3b</td>
<td>0.14 ± 0.02b</td>
</tr>
<tr>
<td>Milled rice-based meal</td>
<td>315.8 ± 5.3a</td>
<td>2.83 ± 0.01b</td>
<td>2.63 ± 0.01b</td>
<td>13.4 ± 3.0a</td>
<td>0.35 ± 0.03a</td>
</tr>
</tbody>
</table>

Data presented as expressed mean ± standard error of the mean \( n=12 \). Data in the same column with different superscript letters denote significant differences at \( P < 0.05 \).
References


Food and Nutrition Research Institute. 2006. Philippine nutrition facts and figures 2003. Manila, Philippines: Food and Nutrition Research Institute, Department of Science and Technology.


