
Dietary fiber characteristics and mineral availability from treated and non-treated brown rice

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Abstract: *Background:* Brown rice has greater mineral content than milled rice. However, due to high dietary fiber and phytic acid content, mineral absorption may be suppressed. *Objective:* To determine the dietary fiber characteristics and mineral availability from treated and non-treated brown rice. *Materials and Methods:* Four varieties of cooked brown rice were used in the study and the same treated to extend the shelf-life of brown rice. Freeze-dried samples were analysed for proximate composition, dietary fiber, phytic acid, iron, zinc and calcium content using standard methods. Mineral availability and dietary fiber fermentation were determined *in vitro*. *Results:* The dietary fiber content of treated brown rice (11.0 ± 0.6 – 11.7 ± 0.1) was significantly greater than that of non-treated brown rice (5.5 ± 0.5 – 6.4 ± 0.2 ; $P < 0.05$). The mineral content and availability from treated and non-treated brown rice did not differ significantly except for mineral availability. Dietary fiber and phytic acid did not show inhibitory effect on mineral availability from both brown rices. The dietary fiber content from both brown rices was fermentable producing short chain fatty acids with greater amounts of propionate. *Conclusion:* Treated and non-treated brown rice are good sources of minerals and dietary fiber, found to be fermentable, and did not inhibit mineral availability.

Keywords: Brown Rice, Dietary Fiber, Minerals

1. Introduction

Brown rice is better than polished rice because it has greater vitamins and minerals than polished rice. However, brown rice contains greater amounts of dietary fiber and phytic acid which may interfere with mineral absorption.

Brown rice has been shown to have greater iron availability *in vitro* than milled rice but lower zinc and calcium availability (1). 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 (2). Studies conducted in Thailand on polished and unpolished rice revealed that iron absorption from polished rice was greater than unpolished rice (3-4). However, because of the high iron content of unpolished rice the absolute amount of iron absorbed from the polished and unpolished rice did not differ significantly (4-5).

Interest in dietary fiber is growing due to the multiple

benefits this dietary components has on health. These fiber components cannot be digested in the small intestines but are carried into the large intestines. If the fiber is fermentable in the large intestine/colon it can release the mineral for absorption (6) and provide substrates for the microorganisms that reside in the colon (7). Fermentation by microorganisms results in the formation of a number of end products that influence physiology and metabolism like the short chain fatty acids e.g. acetate, propionate and butyrate (6-7).

Studies on the interactive effects of dietary fiber and mineral availability from brown rice are scarce. The study will determine the dietary fiber characteristics and mineral availability from different varieties of treated and non-treated brown rice.

2. Materials and Methods

Test Foods: Four varieties of treated and non-treated brown rice were used in the study as follows: Rc160, Rc216, PHB71

and SL8. Brown rice varieties were treated to extend its shelf-life by inhibiting lipase activity to lessen rancidity. All food samples were analysed as freeze-dried cooked brown rice.

Analytical Methods: The proximate analysis of test foods was determined using AOAC methods (8). Total iron, zinc and calcium (9) as well as total dietary fiber and phytic acid (11) was analyzed using AOAC method (10). Tannic acid content of brown rice was also determined (12).

In Vitro Digestion and Dialysis (6)

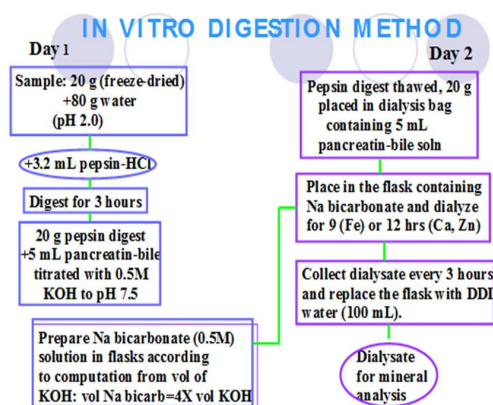


Figure 1. *In vitro* digestion and dialysis simulating conditions in the stomach and small intestine.

Twenty grams of freeze-dried cooked brown rice samples were weighed in 250-mL Erlenmeyer flask. The samples were homogenized and the pH was adjusted to 2.0 using 6N HCl. Pepsin-HCl solution (3.2 mL) was added and the resulting solution was incubated for three hours at 37°C in a water bath shaker (100rpm). From the digested sample solution, twenty grams was aliquoted and added 5mL of pancreatin-bile solution. The pH was adjusted to 7.5 using 0.5M KOH. Four times the volume of the KOH used was equivalent to the volume of 0.5MNaHCO₃ in 100mL dialysis solution. Another 20g of pepsin-digested sample solution was weighed in a dialysis bag (Spectrum Lab) plus 5mL pancreatin-bile solution. The dialysis bag was immersed in the bicarbonate solution. The mixture was incubated for a total of 12 hrs at the same condition as the pepsin digestion. The dialysates were collected every 3 hrs, replacing with 100mL of double deionized water. The dialysates were analyzed for mineral content using AAS. Dialyzable minerals was read in an Atomic Absorption Spectrometer and was used as a measure of mineral availability for absorption in the small intestine (Figure1).

In Vitro Fermentation (6,13)

Freeze dried cooked brown rice samples were fermented *in vitro* using human fecal inoculum. A 0.5 g of the test food was weighed in a serum bottle. Forty (40) mL of fermentation media (mix 2L deionized water, 1L 0.5M sodium bicarbonate buffer solution, 1L macromineral solution, 5 mL of 0.1% resazurin), and 2 mL reducing solution (a mixture of 1.25 g cysteine-HCl+50 pellets of potassium hydroxide in 100 mL

deionized water and 1.25 g sodium sulfide in 100 mL deionized water) were added to the serum bottle and flushed with carbon dioxide until colorless. The bottles were sealed with rubber stoppers and aluminum seal and stored at 4°C. Samples were sealed with rubber and aluminum cap prior to storage at 4°C. The next day the bottles were placed in a water bath for 1-2 hours at 37°C. A 10-mL fecal inoculum (1:15 dilution of fresh feces from a human volunteer) was added into each bottle and the mixture incubated for 24 hours at 37°C. The fermented digest was filtered and read in a high pressure liquid chromatography (HPLC) to measure short chain fatty acids against a volatile acid standard mix (SUPELCO, Philadelphia, USA).

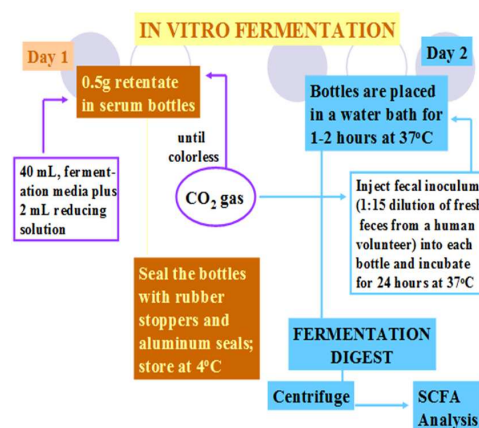


Figure 2. *In vitro* fermentation of dietary fiber simulating conditions in the colon.

Statistical Analysis

Differences between samples were determined by repeated measures analysis of variance and Duncan's Multiple Range Test using SAS Program.

3. Results

All varieties of brown rice were good sources of protein and carbohydrates (Table 1). PHB 71 has the highest fat content while SL8 the highest protein content. The best source of carbohydrates among the different varieties was Rc 216.

Table 1. Proximate Composition of Different Varieties of Cooked Brown Rice, g/100 g Sample

Brown Rice	Rc 160	Rc 216	PHB71	SL8
Moisture	67.0	62.1	67.6	65.5
Ash	0.5	0.6	0.4	0.6
Protein	3.2	3.6	2.6	3.9
Fat	1.1	1.2	1.4	1.3
Carbohydrates	28.2	32.5	28.0	28.7

The best source of iron, zinc and calcium among the different varieties was PHB 71. In general, there were no significant differences in mineral content between non-treated and treated brown rice in different varieties except for SL8 for iron, Rc216 and PHB71 for zinc, and Rc160 and PHB71 for calcium (Table 2; $P < 0.05$). Similar results were obtained for iron and zinc availability for non-treated and treated brown rice except for

Rc160 for iron and Rc216 and PHB71 for zinc. For calcium non-treated and non-treated brown rice (Table 3; P<0.05). availability only Rc216 did not differ significantly between

Table 2. Mineral content of non-treated and treated brown rice, mg/100 g Sample (Mean±SEM)

Rice Variety	Iron		Zinc		Calcium	
	Non-Treated	Treated	Non-Treated	Treated	Non-Treated	Treated
Rc160	0.70±0.10 ^{ay}	0.70±0.10 ^{ay}	1.50±0.10 ^{ay}	1.60±0.10 ^{ax}	24.70±1.30 ^{az}	21.50±0.90 ^{by}
Rc216	1.14±0.04 ^{ax}	1.11±0.05 ^{ax}	1.18±0.02 ^{bx}	1.27±0.06 ^{ay}	26.20±0.20 ^{ay}	25.60±1.50 ^{ax}
PHB71	1.23±0.09 ^{ax}	1.10±0.03 ^{ax}	1.73±0.01 ^{ax}	1.65±0.01 ^{bx}	28.60±0.60 ^{ax}	26.90±0.20 ^{bx}
SL8	1.12±0.01 ^{bx}	1.04±0.03 ^{ay}	1.18±0.02 ^{az}	1.25±0.08 ^{ay}	21.00±1.86 ^{az}	21.90±0.20 ^{ay}

^{ab} denote significant differences between non-treated and treated brown rice at P<0.05

^{xyz} denote significant differences between brown rice varieties at P<0.05.

Table 3. Mineral availability of non-treated and treated brown rice, mg/100 g Sample (Mean±SEM)

Rice Variety	Iron		Zinc		Calcium	
	Non-Treated	Treated	Non-Treated	Treated	Non-Treated	Treated
Rc160	9.3±0.2 ^{yz}	5.8±1.6 ^{yz}	9.4±0.3 ^{ay}	5.5±0.7 ^{by}	19.2±0.2 ^{ax}	14.2±0.5 ^{by}
Rc216	12.6±0.5 ^{ax}	12.1±1.5 ^{ax}	16.9±0.5 ^{ax}	4.2±0.8 ^{by}	10.7±5.0 ^{byz}	17.7±0.9 ^{ax}
PHB71	11.2±0.6 ^{ay}	10.6±0.3 ^{ax}	7.9±0.9 ^{az}	6.8±0.4 ^{ax}	9.5±2.2 ^{az}	7.7±2.0 ^{az}
SL8	8.9±0.9 ^{yz}	7.8±0.2 ^{ay}	6.6±0.7 ^{az}	7.9±1.1 ^{ax}	14.5±1.6 ^{ay}	8.9±1.5 ^{yz}

^{ab} denote significant differences between non-treated and treated brown rice at P<0.05

^{xyz} denote significant differences between brown rice varieties at P<0.05.

Table 4. Dietary fiber and short chain fatty produced after fiber fermentation from treated and non-treated brown rice, Mean±SEM.

Brown Rice Varieties	Dietary Fiber g/100 g	Short Chain Fatty Acids, mg/g		
		Acetate	Propionate	Butyrate
Rc160				
Non-Treated	6.3±0.0 ^b	28.5±0.2 ^a	1208.0±31.6 ^a	2.9±0.3 ^a
Treated	11.1±0.1 ^a	20.7±2.4 ^b	1133.8±29.4 ^b	2.2±0.1 ^b
Rc216				
Non-Treated	6.2±0.2 ^b	39.5±1.4 ^b	1193.0±60.1 ^a	1.5±0.1 ^a
Treated	11.0±0.1 ^a	41.4±1.7 ^a	938.4±39.0 ^b	1.0±0.1 ^b
PHB71				
Non-Treated	5.5±0.5 ^b	5.4±1.0 ^b	1006.2±10.2 ^a	2.6±0.3 ^a
Treated	11.0±0.6 ^a	7.2±0.5 ^a	980.6±28.8 ^a	2.1±0.1 ^b
SL8				
Non-Treated	6.4±0.2 ^b	6.9±0.4 ^a	611.7±97.3 ^b	0.2±0.0 ^c
Treated	11.7±0.1 ^a	6.7±0.0 ^a	977.0±91.3 ^a	0.8±0.0 ^a

^{abc} denote significant differences between non-treated and treated brown rice at P<0.05

Table 5. Phytic and tannic acid content from non-treated and treated brown rice, Mean±SEM

Rice Variety	Phytic Acid, mg/100 g Sample		Tannic Acid, mg/100 g Sample	
	Non-Treated	Treated	Non-Treated	Treated
Rc160	130.6±1.0 ^{yz}	149.3±1.2 ^{yz}	19.4±1.0 ^{ay}	17.5±2.1 ^{az}
Rc216	143.6±0.6 ^{by}	185.3±1.0 ^{ay}	10.2±3.3 ^{yz}	13.3±2.7 ^{yz}
PHB71	224.7±6.1 ^{ax}	220.5±1.3 ^{ax}	19.9±0.4 ^{ay}	20.0±0.2 ^{ay}
SL8	253.7±9.5 ^{aw}	249.4±3.4 ^{aw}	30.1±0.7 ^{bx}	37.6±1.3 ^{ax}

^{ab} denotes significant differences between non-treated and treated brown rice at P<0.05

^{wxyz} denotes significant differences between rice varieties at P<0.05

All varieties of non-treated and treated brown rice were good sources of dietary fiber with treated significantly greater than that of the non-treated brown rice (Table 4; P<0.05). Fermentation of dietary fiber simulating conditions in the colon from non-treated and treated brown rice resulted in the production of short chain fatty acids with propionate > acetate > butyrate Table 4; P<0.05). Phytic acid content of non-treated brown rice differed significantly with treated brown rice except for PHB71 and SL8 (Table 5; P<0.05). All rice varieties contained low tannic acid content, < 100 mg/100 g sample (Table 5).

4. Discussion

The lower mineral availability observed from treated brown rice in comparison to non-treated brown rice may be due to the reduced production of free fatty acids due to control of lipase activity during the treatment of brown rice. A study has shown that free fatty acids may have a role in increasing iron absorption in rats (14). The study suggested that the ferrous iron formation in the lumen may be followed by complexation with free fatty acids, yielding lipophilic complexes that may be

taken up by the mucosal cells, thus increase iron absorption. Other studies showed that oleic acid promotes iron uptake by brush border vesicles from ferrous iron solution (15), and long chain fatty acids especially palmitic and oleic acid increased ferrous uptake by red cell membranes (16). It is possible that different fatty acids have different effects on iron absorption. Another study (17) reported that long chain fatty acids enhanced intestinal mucosal uptake of zinc. The same mechanism may be true for calcium.

The significantly higher dietary fiber content of treated brown rice than that of its corresponding non-treated brown rice may also be due to the fact that during the treatment, the production of free fatty acid is reduced.

Mineral availability in the presence of dietary fiber may not result in the reduction of available minerals for absorption if the dietary fiber is fermentable (6). Minerals can bind with dietary fiber in the small intestinal conditions but if the dietary fiber is fermentable in the colon can be released for absorption in the colon (6). This may be true for brown rice's high fiber-high mineral interaction observed in this study.

The dietary fiber in all varieties of non-treated and treated brown rices was fermentable *in vitro* and produced short chain fatty acids with propionate greater than acetate and butyrate. This result has some health significance. Propionate has been shown to inhibit the activity of the enzyme HMG-CoA reductase, the limiting enzyme for cholesterol synthesis and may therefore have an important role in the prevention for risk of cardiovascular and coronary heart diseases (18).

In conclusion, non-treated and treated brown rice are good sources of minerals and dietary fiber. Mineral availability was not affected by the high dietary fiber content of all varieties of brown rices. The dietary fiber present in brown rices studied were fermentable *in vitro*, and produced more of propionate shown to have some important role in inhibiting cholesterol synthesis. A nutrition intervention study is recommended to validate the promising health and nutritional benefits of brown rice varieties used in this study.

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