

Ascorbic Acid : Effect on Food Iron Availability from Strict Thai Vegetarian Meals

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The effect of ascorbic acid on nonheme iron absorption from 2 strict Thai vegetarian meals containing considerable amounts of tannin and phytate was investigated. The ⁵⁹Fe and ⁵⁵Fe extrinsic tag method was used to labeled the nonheme iron. Iron absorption from vegetarian tannin and phytate meals improved progressively with increased level of ascorbic acid, 2-3 times with 100 mg and 4-5 times with 200 mg. The average amount of iron absorbed per 2000 kcal increased from 0.37 mg to 0.86 mg and 1.45 mg with the addition of 100 mg and 200 mg ascorbic acid respectively ($p < 0.001$). Considering the limited caloric intakes and the iron content in the meals, the amount of iron absorbed from vegetarian meals without ascorbic acid was not able to meet certain requirements for children, adolescents and menstruating women. The minimal requirement for dietary iron needed to be absorbed is 0.96 mg for 97.5th percentile of up to 1 year children and 2.38 mg for menstruating girls and women. The addition of 200 mg of ascorbic acid could provide only 60% of the total daily requirements. The vegetarian meals as compared with ordinary mixed meals can provided most of the nutrients in the amounts close to or above the recommended intake according to the Recommended Daily Allowances (RDA). However, the amounts of iron absorbed from these meals are quite precarious and fail to meet the requirements for the important target groups. It is suggested that, vegetarian diets can assure nutrient adequacy and promote health when they are planned and chosen in the line with scientific nutrition principles.

INTRODUCTION

The bioavailability of a number of minerals may be altered by the special characteristics of vegetarian diets. Iron is an example of one mineral that may be affected. It has been reported that iron deficiency anemia is most prevalent and severe in population in developing country subsisting on predominantly vegetarian diets⁽¹⁾. Dwyer et al reported mild iron deficiency in 25% of preschool vegetarian children⁽²⁾.

Bindra and Gibson found a high prevalence of iron deficiency with normal iron intakes in adult lacto-ovo vegetarians⁽³⁾. In Thailand, poor iron nutritional status among female vegans has also been reported^(4, 5). As vegetarian diets are mostly plant oriented products, the ability to provide for adequacy of iron nutrient depending on the amount of available iron in the diet and the net effect of the balance between the factor enhancing an inhibiting iron absorption.

Many chemical ligands in food are known to be powerful promoters of nonheme iron absorption. These include ascorbic acid, citric acid, aminoacids and meat protein. The properties of ascorbic acid have received most attention since its content of the diet is more easily modified than other contents. The enhancing effect of ascorbic acid on the absorption of nonheme iron has been observed repeatedly by use of ⁵⁵Fe/⁵⁹Fe extrinsic tag method^(6, 7). Its effect is strongly dose-related^(8, 9). Other ligands such as phytate, fibre components and iron binding phenolic compounds inhibit iron absorption^(10, 11, 12).

The purpose of this study was to determine the dietary absorption of iron from some strict Thai vegetarian meals containing considerable amounts of iron-binding phenolic compounds (tannin) and phytate and, the possibility to counteract the inhibition of tannin and phytate by increasing the content of ascorbic acid (AA) in the amounts of nutritionally realistic.

MATERIALS AND METHODS

Subjects

A total of 24 male subjects participated in the study were healthy volunteers, aged 18 to 28 years. They were given oral and written information about the aims and pro-

cedures of the study. The project and protocol were approved by the Human Subjects Committee of Siriraj Hospital Medical School.

Test meals

Iron absorption was measured in 2 restricted vegetarian Thai meals. Both were rice-based meals prepared as is normally done in the laboratory kitchen. (1) Meal with tannin : Rice (248 g) + Swamp cabbage (*Ipomoea reptans*)(50 g) + Mushroom (40 g) + Sweet and sour soup (200 g), (2) Meal with phytate : Rice (248 g) + Soy protein (70 g) + Mushroom (70 g) + Sweet soup with spices (70 g). Samples from both meals were blended into a homogeneous slurry. Aliquots of each meal were taken for total iron content⁽¹³⁾, total phosphorus and phytic acid phosphorus⁽¹⁴⁾, and iron binding phenolic compounds⁽¹⁵⁾ and ascorbic acid⁽¹⁶⁾. Chemical composition of meals is shown in Table 1. The first meal contained 81 mg tannin and 46.5 mg phytate. The second meal contained 90.7 mg phytate.

Iron absorption measurements

Iron absorption was measured by the use of sequential ⁵⁵Fe and ⁵⁹Fe labeled^(6, 7). All test meals were given at 12.00 noon after an overnight fast and a standard breakfast

Table 1 Energy intake per meal and meal composition of the 2 vegetarian meals (1) meal with tannin and (2) meal with phytate

Dietary intake	Test meal	
	(1) Tannin meal	(2) Phytate meal
Energy (kcal)	547.30	583.00
Food weight (g)	538.00	458.00
Total iron (mg)	2.44	3.01
Phosphorus (mg)	511.70	505.60
Phytate-P (mg)	46.50	90.70
Tannin (mg)	81.00	0

served at 7.30 am. After the meals no foods or drinks was allowed for 3 hours. Each test meal was labeled with 46.3 kBq ⁵⁹Fe or 55.5 kBq ⁵⁵Fe, carrier free, high specific activity in 0.1 mol HCl/litre. A blood sample was drawn 2 weeks after serving the first meal (without AA) and second test meal (with 100 mg AA) on alternate days and a final blood samples was obtained 2 weeks after the third meals (with 200 mg AA) to measure the increase in red cell radioactivity. Analysis of ⁵⁵Fe and ⁵⁹Fe in blood was made by using a modification of the method described by Eakins and Brown with a liquid scintillation spectrometer⁽¹⁷⁾. Percentage absorption was calculated on the basis of blood volume estimated from body weight⁽¹⁸⁾.

Statistical analysis

All calculations were made by using the Microsoft Excel 5.0 computer program. Statistical analyses were made with the SPSS program for Windows.

RESULTS AND DISCUSSION

The results of absorption measurements from 2 vegetarian meals and the effect of inclusion of 100 and 200 mg of ascorbic acid is shown in Table 2 and Figure 1. The results from both meals are within the ab-

sorption of nonheme iron ranges from 2% to 20%. In the vegetarian tannin meal, 100 and 200 mg of ascorbic acid increased the absorption from 4.1% to 8.5% and 18.2% and in the vegetarian phytate meal it increased from 3.5% to 9.2% and 12.5% respectively (p<0.001). They are progressively increased with increase in the level of ascorbic acid, 2 to 3 folds with the addition of 100 mg and 3 to 5 folds with 200 mg added. Summary of the caloric intake, amounts of iron absorbed per meal, per 1000 kcal and per 2000 kcal are tabulated in Table 3. As shown in Table 3 the iron absorption at the energy intake of 2000 kcal varied from 0.36 to 0.76 and 1.6 mg for meal with tannin and from 0.38 to 0.96 and 1.3 mg for meal with phytate. An average for both meals is from 0.37 to 0.86 and 1.45 mg.

The nutritive value of a diet for certain nutrient must be based on its ability to meet requirements for certain target groups. As in Table 3 the bioavailability of vegetarian meals vary from 3.5% to 18% as compare to the ranges from 5% to 12% in Western-type vegetarian meals⁽¹⁹⁾. The daily dietary intake of iron of 7.33 and 9.04 mg of both test meals were lower than the recommended daily allowances of 10 to

Table 2 Iron absorption from vegetarian meals without and with 100 and 200 mg ascorbic acid

	mg/meal			Iron absorption	
	AA	Phytate	Tannin	%	Ratio*
(1) Meal with tannin	0	46	81	4.1	1
(Swamp cabbage)	100	46	81	8.5	2.07
	200	46	81	18.2	4.43
(2) Meal with phytate	0	90.7	0	3.5	1
(Soy protein)	100	90.7	0	9.2	2.63
	200	90.7	0	12.5	3.57

*Absorption ratio between without and with 100 and 200 mg of ascorbic acid (AA).

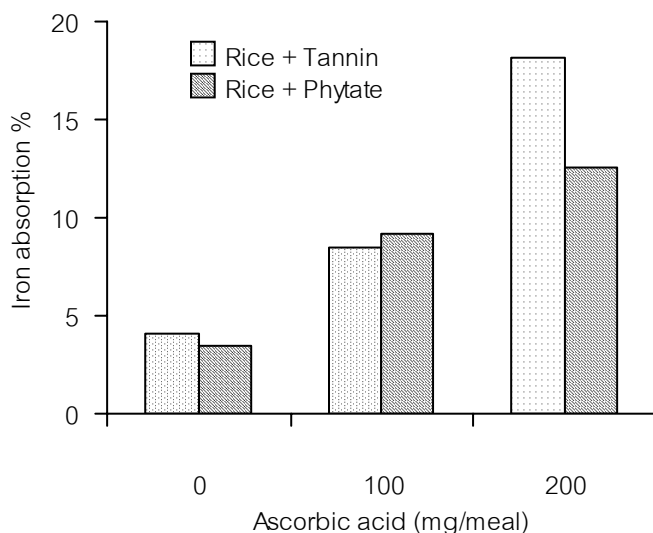


Fig. 1 Iron absorption from vegetarian meals without and with 100 and 200 mg ascorbic acid.

18 mg for all age/sex groups⁽²⁰⁾, lower than that of Seventh-day Adventist vegetarian women in Canada (12.5 mg/d) reported by Anderson et al.⁽²¹⁾, and much lower than that of vegetarian women in the United State (16mg/d) reported by Hardinge and Stare⁽²²⁾, and in general lower than the mean intake (12.9 mg/d) surveyed from general Thai population⁽²³⁾. These findings, however, does not imply that all Thai veg-

etarian meals have low intrinsic iron content since it has been shown that an average iron content surveyed in 43 restricted Thai vegetarian meals were 4.16 mg/meal which corresponded to a daily intake of 12.5 mg or 7.7 mg/1000 kcal reported by Sritongkul et al.⁽²⁴⁾. The iron content in mixed Western type meal has been shown to be very constant being approximately 6 to 12 mg/1000 kcal⁽²⁰⁾. In this study the

Table 3 Iron absorbed per 1000 and 2000 kcal from vegetarian meals without and with 100 and 200 mg ascorbic acid.

Test meal	(1) Meal with tannin			(2) Meal with phytate		
Energy (kcal/d)	1641			1749		
Total iron (mg/meal)	2.44			3.01		
Daily iron intake (mg)	7.33			9.04		
Iron density (mg/1000kcal)	4.46			5.15		
Ascorbic acid (mg)	0	100	200	0	100	200
% Iron Absorption	4.1	8.5	18.2	3.5	9.2	12.5
Iron absorbed (mg/meal)	0.30	0.63	1.32	0.33	0.84	1.14
mg Iron absorbed/1000kcal	0.18	0.38	0.80	0.19	0.48	0.65
mg Iron absorbed/2000kcal	0.36	0.76	1.60	0.38	0.96	1.30

iron contents of 4.3 and 5.15 mg/1000kcal were lower than the recommended values. Comparisons of the mean daily energy and iron intake and iron densities in various group of vegetarians to the recommended values were shown in Table 4^(3, 20, 21, 23-26).

Vegetarian diets generally contain high quantities of fiber, phytate and tannin, which have been found to bind to iron and reduce bioavailability. Kramer et al.⁽²⁷⁾ reported that the energy level of vegetarian diet is also an important factor relative to mineral adequacy. The low energy lifestyle and low energy intake among vegetarians

make its sometimes difficult to meet the requirement for certain nutrient.

Based on FAO/WHO Report 1988 as given in Table 5⁽²⁸⁾. The iron requirements at 97.5th percentile for menstruating girls and women is 2.38 mg. In this study the iron absorbed per 2000 kcal meal with 200 mg of ascorbic acid could provide only 60% of FAO/WHO recommendation. To meet these requirements it is suggested that the meals needs to contain higher content of iron and ascorbic acid and the minimal levels of phytate and iron-binding phenolic compounds.

Table 4 Mean daily energy and iron intake by female vegetarians and their iron nutrient density.

Type	Fe intake (mg)	Energy (kcal)	Iron density (mgFe/1000 kcal)	References
Indian vegans	10.6	1412	7.5	Kelsay (25)
American vegans	12.3	1742	7.1	Kelsay (25)
Lacto-ovo-vegetarian	14.4	1711	8.4	Bindra (3)
Lacto-ovo-vegetarian	12.7	1900	6.7	Abdulla (26)
Seventh-day Adventist	12.5	1630	7.7	Anderson (21)
Thai vegetarian	12.5	1624	7.7	Nopamon (24)
Regular Thai meals*	12.9	1749	7.4	Vina (23)
RDA**	10.0-18.0	2200	6.0-12	RDA (20)

* Averaged from different regions of Thailand ** Recommended Daily Allowances

Table 5 Daily iron requirements based on FAO/WHO Report 1988⁽²⁸⁾.

Group	Age (yrs)	Average weight (kg)	Daily iron requirement (mg/d) 97.5 th Percentile
Children	0.25-1	8	0.96
	1-2	11	0.61
	2-6	16	0.70
	6-12	29	1.17
Boys	12-19	53	2.02
Girls	12-19	51	2.38
Adult males		70	1.27
Adult females			
Menstruating	20-49	55	2.38
Menopausal	50+	55	0.96
Lactating		55	1.31

CONCLUSION

Dietary iron deficiencies are most common among vegetarians whose diet are extremely restricted. Absorption of these types of meals is impaired by the presence of high levels of phytate and iron binding phenolic compounds. The consumption of ascorbic acid with a vegetarian meal containing primarily inorganic nonheme iron could improve the absorption of iron for the vegetarians whose diets contains components leading to decreased iron availabil-

ity. It is possible that vegetarians can avoid problems in iron status by limiting fibre, phytate and tannin to a reasonable degree and maintaining an adequate energy intake.

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