Inhibition of food iron absorption by coffee

Article *in* American Journal of Clinical Nutrition · April 1983

DOI: 10.1093/ajcn/37.3.416 · Source: PubMed

Inhibition of food iron absorption by coffee[1-3]

Timothy A Morck,[4] PhD, Sean R Lynch, MD, and James D Cook, MD

ABSTRACT Dual isotope studies were performed in iron replete human subjects to evaluate the effect of coffee on nonheme iron absorption. A cup of coffee reduced iron absorption from a hamburger meal by 39% as compared to a 64% decrease with tea, which is known to be a potent inhibitor of iron absorption. When a cup of drip coffee or instant coffee was ingested with a meal composed of semipurified ingredients, absorption was reduced from 5.88% to 1.64 and 0.97%, respectively, and when the strength of the instant coffee was doubled, percentage iron absorption fell to 0.53%. No decrease in iron absorption occurred when coffee was consumed 1 h before a meal, but the same degree of inhibition as with simultaneous ingestion was seen when coffee was taken 1 h later. In tests containing no food items, iron absorption from NaFeEDTA was diminished to the same extent as that from ferric chloride when each was added to a cup of coffee. These studies demonstrate that coffee inhibits iron absorption in a concentration-dependent fashion. *Am J Clin Nutr* 1983;37:416–420.

KEY WORDS Coffee, iron absorption

Introduction

Tea has a potent inhibitory effect on the absorption of nonheme iron (1–3). For example, Disler et al (1) demonstrated that iron absorption from a meal was reduced by as much as 87% when tea was included. Coffee is another beverage that is often consumed with meals. Its effect on iron absorption has not been studied in detail although Derman et al (4) observed a 37% reduction when coffee was added to a meal containing maize. Because coffee is commonly consumed in countries where iron-deficiency anemia is prevalent, a significant inhibitory effect on dietary iron absorption has nutritional relevance. We report here the inhibitory effect of coffee on nonheme iron absorption in human subjects.

Methods

Subjects

Thirty-seven volunteer subjects (36 men and one postmenopausal woman) ranging in age from 18 to 50 yr participated in four separate iron absorption studies. All were in good health and denied any history of gastrointestinal disorders that might affect iron absorption. The mean of serum ferritin measurements on days 1, 14, and 20 of the study show iron status to be uniformly normal (5). Written informed consent was obtained from each volunteer before the study and all experimental procedures were approved by the Human Subjects Committee at the University of Kansas Medical Center.

Absorption measurements

Each study included four test meals which were labeled alternately with either ^{55}Fe or ^{59}Fe and given to the subjects between 7 and 9 AM after a 10-h fast. Only water was allowed for the subsequent 3 h. Meals A and B were administered on consecutive days and meals C and D were similarly given 2 wk later. Nonheme iron absorption was measured by incorporated red cell radioactivity in blood samples drawn two weeks after each pair of meals. Radioiron measurements were made on duplicate 10-ml blood samples (5). Sufficient counts were obtained on each sample to reduce the net counting error for each isotope to less than ±2% in subjects absorbing more than 1% of the test dose. Absorption was calculated on the basis of blood volume, and erythrocyte incorporation was assumed to be 80% of absorbed iron (5).

Test meals

Four studies were conducted in which two types of meals were served with different beverages (**Table 1**). In

---

[1] From the Division of Hematology, Department of Medicine, University of Kansas Medical Center, Kansas City, KS 66103.

[2] Supportd by Contract DSAN-C-0045 from the US Agency for International Development.

[3] Address reprint requests to: James D Cook, MD, Director of Hematology, University of Kansas Medical Center, Kansas City, KS 66103.

[4] Present address: Veterans Administration Medical Center, Hampton, VA 23667.

Received April 12, 1982.

Accepted for publication August 31, 1982.

studies 1 and 3, the test meal was a beef patty (113 g uncooked weight), a bun, and a 200 ml drink of water, tea, or coffee. In study 2, a mixture of semipurified ingredients was used for all four test meals; each 340 ml serving contained dried egg albumen (Monark Egg Corp, Kansas City, MO), corn syrup solids (Dri-Sweet 36, Hubinger Co, Keokuk, IA), corn oil, and $FeCl_3 \cdot 6\ H_2O$ which provided 14.7 g protein, 68 g carbohydrate, 35 g fat, and 4.1 mg iron. Coffee or water (200 ml) was served with each meal in study 2. The test dose in study 4 consisted only of 200 ml of either water or instant coffee to which 3 mg iron as either $FeCl_3 \cdot 6\ H_2O$ or NaFeEDTA was added.

The tea for study 1 was prepared by adding boiling water to dry tea (Orange Pekoe and Pekoe Cut Black Tea, Lipton Inc, Englewood Cliffs, NJ; 1.75 g/200 ml serving) and steeping for 4 min. Drip coffee (studies 1 and 2) was made in an automatic drip coffee maker (Proctor-Silex) using 70 g Folger's drip grind coffee (Folger Coffee Co, Cincinnati, OH) and 1625 ml cold tap water. Instant coffee (studies 2, 3, and 4) was prepared by adding 200 ml boiling water to 1.5 g freeze-dried coffee (Taster's Choice, Nestle Company, White Plains, NY) unless otherwise stated.

The extrinsic tag method was used throughout (6, 7). The radioiron was mixed with 0.1 mg carrier iron as $FeCl_3 \cdot 6\ H_2O$ in 1 ml 0.01 N HCl. The radioiron label was sprinkled over the beef patty in meals containing a hamburger and was added directly to the semipurified liquid meal in study 2. In study 4, the radioiron tag was added directly to the beverage which contained 3 mg iron as either NaFeEDTA or $FeCl_3 \cdot 6\ H_2O$. A preliminary investigation demonstrated that there was complete exchange between NaFeEDTA and $FeCl_3 \cdot 6\ H_2O$.

Statistics

Because the distribution of iron absorption data expressed as percentage of administered dose is positively skewed, individual values were converted to logarithms for statistical analysis and the results reconverted to the antilogarithm to recover the original units (8). All mean values for iron absorption and meal ratios are reported as geometric means. The paired *t* test was used to compare iron absorption from any two meals within the same study.

TABLE 1
Composition of test meals*

Study	Meal type	Beverage added to meals			
		A	B	C	D
1	STD	Water	Tea	Coffee†	REF
2	SP	Water	Coffee†	Coffee‡	Coffee‡
3	STD	Water	Coffee‡	Coffee‡	Coffee‡
4	None	Water	Water	Coffee‡	Coffee‡

* Abbreviations: REF, reference dose without food; STD, standard meal; SP, semipurified meal.
† Drip cofffee.
‡ Freeze-dried instant coffee.

Results

Study 1 was performed to compare the effect of tea and coffee on iron absorption from a hamburger meal. When water was given with this meal, 3.71% of the nonheme iron was absorbed (meal A, **Table 2**). With tea as the beverage (meal B) absorption fell to 1.32%, representing a highly significant 64% inhibition ($p < 0.001$). When a cup of

TABLE 2
Effect of tea and coffee on iron absorption from a standard meal

Subject	Age	Packed cell volume	Serum ferritin	Iron absorption				Absorption ratios		
				Water (A)	Tea (B)	Coffee (C)	REF* (D)	B/A	C/A	B/C
	yr	*%*	*μg/l*		*% of dose*					
1	29	48	65	0.96	0.48	1.08	10.85	0.50	1.12	0.44
2	26	44	68	1.76	0.56	0.86	11.63	0.31	0.48	0.65
3	25	45	67	1.78	1.47	4.30	4.33	0.82	2.41	0.34
4	26	46	97	2.53	1.68	2.02	19.06	0.66	0.79	0.83
5	30	44	156	2.71	1.82	2.47	10.96	0.67	0.91	0.73
6	22	46	102	4.16	2.18	2.22	14.37	0.52	0.53	0.98
7	26	43	47	5.55	0.87	2.05	19.55	0.15	0.36	0.42
8	23	43	34	5.81	0.30	0.51	23.21	0.05	0.08	0.58
9	28	43	58	6.91	1.70	4.91	20.55	0.24	0.71	0.34
10	22	45	34	8.75	3.43	4.21	26.02	0.39	0.48	0.81
11	19	44	27	11.21	5.32	7.93	36.81	0.47	0.70	0.67
Mean†	25	45	60	3.71	1.32	2.25	15.73	0.36‡	0.61§	0.59‡
			−1 SE	2.94	1.01	1.75	13.22	0.28	0.47	0.53
			+1 SE	4.68	1.71	2.88	18.71	0.45	0.78	0.65

* REF, reference dose.
† Geometric means except age and packed cell volume.
‡ $p < 0.001$.
§ $p < 0.05$.

drip coffee was taken with the hamburger (meal C), a 39% decrease in iron absorption to a mean of 2.25%, occurred ($p < 0.05$). A direct statistical comparison indicated that coffee was significantly less inhibitory than tea ($B/C = 0.59$, $p < 0.001$). Meal D consisted of a reference dose of ferrous ascorbate containing 3 mg iron as $FeSO_4$ and 18.9 mg ascorbic acid. Mean absorption in these iron replete subjects averaged 15.73%.

Study 2 was designed to compare the effect of drip and instant coffee and to determine whether the inhibitory effect of coffee is dose related. In general, coffee had a greater inhibitory effect on iron absorption from the semipurified meal (**Table 3**). Absorption from meal B containing drip coffee averaged 1.64% as compared to 5.88% from the control meal (A), a reduction of 72%. A somewhat greater decrease of 83% was observed when a cup of instant coffee was ingested with the meal (C). Doubling the concentration of the instant coffee caused a further 45% decrease in iron absorption which was also statistically significant ($D/C = 0.55$, $p < 0.01$).

Study 3 examined the effect of varying the time when coffee was ingested in relation to the hamburger meal (**Table 4**). When the coffee and hamburger were taken simultaneously (meal C), iron absorption fell from a control mean of 8.12 to 4.58% ($p < 0.05$). Coffee taken 1 h before the hamburger (meal B) led to a small decrease in mean absorption that was not statistically significant. On the other hand, with coffee taken 1 h after the hamburger (meal D), the degree of inhibition was similar to that observed when the beverage and meal were consumed simultaneously.

In this final study (study 4), the effect of coffee on iron absorption from NaFeEDTA was compared with that from $FeCl_3$ in the absence of food (**Table 5**). Although percentage absorption from NaFeEDTA in water was slightly lower (3.83%) than from $FeCl_3$ (5.04%), the difference was not statistically significant. When the same forms of iron were given with coffee, 70% decreases in absorption were observed ($C/A = 0.30$, $D/B = 0.31$, $p < 0.001$). Thus, percentage absorption from $FeCl_3$ relative to NaFeEDTA was constant regardless of the beverage ($A/B = 0.76$, $C/D = 0.73$).

Discussion

The studies reported here demonstrate that coffee, like tea, markedly reduces iron absorption. These results are in keeping with some previous observations by Layrisse et al

TABLE 3
Effect of type and strength of coffee on iron absorption from a semipurified meal

Subject	Age	Packed cell volume	Serum ferritin	Iron absorption				Absorption ratio			
					Coffee						
				Water (A)	Drip (B)	FD* (1.5 g) (C)	FD (3.0 g) (D)	B/A	C/A	D/A	D/C
	yr	*%*	*µg/l*	*% of dose*							
1	44	55	55	1.35	1.06	0.36	0.23	0.78	0.26	0.17	0.63
2	30	49	76	3.22	2.45	2.57	1.65	0.76	0.79	0.51	0.64
3	24	39	114	4.48	1.88	0.43	0.33	0.41	0.09	0.07	0.76
4	23	43	114	5.11	1.10	0.27	0.23	0.21	0.05	0.04	0.85
5	35	55	132	6.22	0.86	0.40	0.17	0.13	0.06	0.02	0.42
6	50	37	56	9.03	3.37	2.45	2.21	0.37	0.27	0.24	0.90
7	28	45	46	9.51	0.83	2.62	1.43	0.08	0.27	0.15	0.54
8	27	45	86	10.00	1.91	1.11	0.28	0.19	0.11	0.02	0.25
9	31	43	181	15.98	3.56	2.56	0.90	0.22	0.16	0.05	0.33
Mean†	31	44	87	5.88	1.64	0.97	0.53	0.28‡	0.17‡	0.09‡	0.55§
			−1 SE	4.60	1.36	0.70	0.38	0.22	0.12	0.07	0.48
			+ SE	7.52	1.98	1.36	0.75	0.36	0.22	0.13	0.64

* FD, freeze-dried instant.
† Geometric means except age and packed cell volume.
‡ $p < 0.001$.
§ $p < 0.01$.

TABLE 4
Effect of time of consumption of coffee on iron absorption from a standard meal

Subject	Age	Packed cell volume	Serum ferritin	Iron absorption: Water (A)	Coffee added: Before (B)	With (C)	After (D)	Absorption ratios: B/A	C/A	D/A	D/C
	yr	*%*	*μg/l*	*% of dose*							
1	24	46	28	1.86	3.00	1.73	2.72	1.61	0.93	1.46	1.57
2	19	49	51	3.98	3.18	4.37	3.90	0.79	1.09	0.97	0.89
3	25	44	95	5.48	2.20	3.33	2.53	0.40	0.60	0.46	0.75
4	25	46	48	9.81	8.67	2.00	2.02	0.88	0.20	0.20	1.01
5	19	48	30	10.61	8.78	2.76	2.76	0.82	0.26	0.26	1.00
6	18	50	22	19.95	17.70	10.16	13.93	0.88	0.50	0.69	1.37
7	28	44	22	27.72	14.06	30.13	19.56	0.50	1.08	0.70	0.64
Mean*	23	47	37	8.12	6.30	4.58	4.55	0.78	0.56†	0.56†	0.99
			−1 SE	5.70	4.62	3.12	3.23	0.66	0.44	0.43	0.88
			+1 SE	11.57	8.60	6.72	6.41	0.92	0.73	0.73	1.12

* Geometric means except age and packed cell volume.
† $p < 0.05$.

TABLE 5
Effect of coffee and water on absorption of iron from NaFeEDTA and $FeCl_3$

Subject	Age	Packed cell volume	Serum ferritin	Iron absorption: Water: NaFeEDTA (A)	$FeCl_3$ (B)	Coffee: NaFeEDTA (C)	$FeCl_3$ (D)	Absorption ratios: A/B	C/D	C/A	D/B
	yr	*%*	*μg/l*	*% of dose*							
1	23	47	395	1.42	1.60	0.40	0.17	0.89	2.35	0.28	0.11
2	32	46	141	2.55	4.15	0.72	0.92	0.61	0.78	0.28	0.22
3	31	44	179	2.61	7.38	0.63	0.95	0.35	0.66	0.24	0.13
4	19	45	60	3.30	1.73	1.08	1.02	1.91	1.06	0.33	0.59
5	30	47	55	3.57	1.98	0.83	0.90	1.80	0.92	0.23	0.45
6	18	45	31	4.10	5.97	0.72	4.50	0.69	0.16	0.18	0.75
7	28	46	122	4.13	3.23	1.75	1.50	1.28	1.17	0.42	0.47
8	28	45	102	4.78	9.82	1.01	1.66	0.49	0.61	0.21	0.17
9	25	44	65	5.68	11.53	4.95	5.48	0.49	0.90	0.87	0.48
10	27	49	27	13.60	29.30	3.71	11.02	0.46	0.34	0.27	0.38
Mean*	26	46	86	3.83	5.04	1.14	1.57	0.76	0.73	0.30†	0.31†
			−1 SE	3.18	3.74	0.88	1.08	0.63	0.58	0.26	0.25
			+1 SE	4.62	6.79	1.47	2.28	0.92	0.92	0.34	0.39

* Geometric means except age and packed cell volume.
† $p < 0.001$.

(9) who studied the availability of ferrous sulfate-fortified sugar added to several beverages. Although a direct comparison between the effect of coffee and other drinks was confounded by the use of different groups of subjects, the bioavailability of the iron was considerably lower when added to coffee than when added to soft drinks or orange juice. Absorption from iron-fortified sugar was reduced by 44% in a meal containing a vegetable, meat, and coffee and by 75% when the sugar was used in coffee alone. Coffee with milk was twice as inhibitory as black coffee.

Tea is thought to influence iron absorption at a luminal level by the formation of insoluble iron tannates. Our study suggests that coffee may also exert its effect in the lumen since the reduction in absorption was most marked when the coffee was taken with the meal or 1 h later. A significant fraction of the meal would still be in the stomach after 1 h since the half time of gastric emptying for this hamburger meal is approximately 180 min (Skikne BS, Lynch SR, Cook JD, unpublished observations).

Recent in vitro experiments suggest that coffee may inhibit iron absorption by a chemical mechanism different from that of tea. Kojima et al (10) compared the effect of different beverages on the amount and chemical form of soluble iron in pinto bean suspensions after incubations at pH 2 and 6. Whereas tea reduced the proportion of soluble iron to only 12% of the quantity in bean suspensions without additions, drip and instant coffee had no significant effect on iron solubility. Nevertheless, all soluble iron in both beverages was oxidized to the ferric state. Our studies suggest that this form of iron has limited availability for absorption in humans.

These findings may have important implications for iron nutrition because coffee is a favored beverage in many parts of the world. However, the effect on iron balance is difficult to gauge since the methods of preparation and patterns of consumption, both of which influence absorption, differ considerably within and between populations. The inhibitory effect of coffee may also be relevant to the choice of the vehicle and iron salt for fortification programs. Sugar, which is commonly used in coffee, has been proposed as a vehicle for iron fortification (11). It has also been suggested that NaFeEDTA is the most suitable iron compound for fortifying sugar because of its greater chemical stability (11–15). A recent study demonstrating that maize meal porridge and bran reduce iron absorption from ferrous sulfate but have little effect on NaFeEDTA (15) supports the contention. On the other hand, tea is equally inhibitory to ferrous sulfate and NaFeEDTA and our findings suggest that this also is true of coffee consumed alone; 70% inhibition was observed for both ferrous sulfate and NaFeEDTA. Nevertheless, Layrisse et al (11) found that when a bulky breakfast meal (120 g black bean gruel, 4 tortillas, and a bread roll) was ingested with a cup of coffee, absorption from NaFeEDTA was significantly better than from ferrous sulfate. It would appear that the use of NaFeEDTA to fortify sugar used in beverages would be advantageous only if the beverages are taken with meals.

References

1. Disler PB, Lynch SR, Charlton RW, Torrance JD, Bothwell TH. The effect of tea on iron absorption. Gut 1975;16:193–200.
2. Disler PB, Lynch SR, Torrance JD, Sayers MH, Bothwell TH, Charlton RW. The mechanism of the inhibition of iron absorption by tea. S Afr J Med Sci 1975;40:109–16.
3. de Alarcon PA, Donovan ME, Forbes GB, Landaw SA, Stockman JA. Iron absorption in the thalassemia syndromes and its inhibition by tea. N Engl J Med 1979;300:5–8.
4. Derman D, Sayers M, Lynch SR, Charlton RW, Bothwell TH, Mayet F. Iron absorption from a cereal diet containing cane sugar fortified with ascorbic acid. Br J Nutr 1977;38:261–9.
5. Bothwell TH, Charlton RW, Cook JD, Finch CA. Iron metabolism in man. Oxford: Blackwell Scientific, 1979.
6. Cook JD, Layrisse M, Martinez-Torres C, Walker R, Monsen E, Finch CA. Food iron absorption measured by an extrinsic tag. J Clin Invest 1972;51:805–15.
7. Bjorn-Rasmussen E, Hallberg L, Walker RB. Food iron absorption in man. I. Isotopic exchange of iron between food iron and inorganic iron salt added to food: studies on maize, wheat, and eggs. Am J Clin Nutr 1972;25:317–23.
8. Cook JD, Layrisse M, Finch CA. The measurement of iron absorption. Blood 1969;33:421–9.
9. Layrisse M, Martinez-Torres C, Renzi M, Velez F, Gonzalez M. Sugar as a vehicle for iron fortification. Am J Clin Nutr 1976;29:8–18.
10. Kojima N, Wallace D, Bates GW. The effect of chemical agents, beverages, and spinach on the in vitro solubilization of iron from cooked pinto beans. Am J Clin Nutr 1981;34:1392–401.
11. Layrisse M, Martinez-Torres C, Renzi M. Sugar as a vehicle for iron fortification. Further studies. Am J Clin Nutr 1976;29:274–9.
12. Layrisse M, Martinez-Torres C. Fe(III)-EDTA complex as iron fortification. Am J Clin Nutr 1977;30:1166–74.
13. Viteri FE, Garcia-Ibanez R, Torun B. Sodium iron NaFeEDTA as an iron fortification compound in Central America. Absorption studies. Am J Clin Nutr 1978;31:961–71.
14. Martinez-Torres C, Romano EL, Renzi M, Layrisse M. Fe(III) EDTA complex as iron fortification. Further studies. Am J Clin Nutr 1979;32:809–16.
15. MacPhail AP, Bothwell TH, Torrance JD, Derman DP, Bezwoda WR, Charlton RW, Mayet F. Factors affecting the absorption of iron from Fe(III)EDTA. Br J Nutr 1981;45:215–27.