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Heme Iron Content in Selected Ready-to-Serve Beef Products

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Selected ready-to-eat meat foods, e.g., beef burger, frankfurter, beef steak, and roast beef, from fast-food restaurants and groceries were analyzed for total iron, heme iron, and nonheme iron contents. The different meat products contained similar amounts of total iron. The heme iron contents (ready-to-serve basis) ranged from 16.0 to 26.9 μg/g for beef burger, from 6.2 to 14.6 μg/g for frankfurter, from 13.4 to 36.3 μg/g for beef steak, and from 11.3 to 23.7 μg/g for roast beef. Percentage heme iron ranged from 50.2 to 63.8% for these meat foods. Total iron, heme iron, percentage heme iron, and nonheme iron varied significantly ($p < 0.01$) among meat foods, sources, and replications.

INTRODUCTION

Dietary heme iron is important in iron nutrition because factors like phytates do not interfere with its absorption (Bezwoda et al., 1983; Brown et al., 1968; Conrad et al., 1966; Hallberg and Sölvell, 1967) and it is much better absorbed (>15%) than nonheme iron (<5%) (Hussain et al., 1965; Layrisse et al., 1974; Schricker et al., 1982). Monsen et al. (1978) assumed that 40% of the iron in meat, fish, and poultry is heme and that 23% of dietary heme and 2–8% of dietary nonheme iron is absorbable. On this basis, they calculated absorbable dietary iron and noted that predicting the dietary iron availability depends on accurate estimates of heme and nonheme iron. However, there is limited information regarding the heme iron content of meat products as consumed (i.e., generally cooked). The available data are largely for raw meat, and the determined values vary widely. Since heat destroys heme iron (Igene et al., 1979; Schricker and Miller, 1983; Jansuittivechakul et al., 1985; Buchowski et al., 1988, King et al., 1990), it is inaccurate to estimate the heme iron content of cooked meat foods on the basis of analysis of raw meat. Cooking time and source of meat affect heme iron content (Hendricks et al., 1987; Buchowski et al., 1988). Thus, it would be more accurate to estimate absorbable dietary iron intakes on the basis of actual heme iron contents of the different meat, fish, and poultry products ready-to-serve.

Not much information is available on the heme iron and nonheme iron content of ready-to-serve meat products such as beef burger, frankfurter, beef steak, and roast beef. The objectives of this study were (1) to quantify the total iron, heme iron, and nonheme iron content in ready-to-serve meat products, (2) to calculate the percentage of meat iron that is heme, and (3) to compare the different iron forms in meat products from different sources and prepared in different ways.

MATERIALS AND METHODS

Sample Preparation. All the meat samples were purchased ready-to-serve from fast-food restaurants and grocery stores and analyzed for moisture and heme iron on the day of purchase. Beef burger was sampled from 6 sources; frankfurter from 3 sources; beef steak from 4 sources; and roast beef from 10 sources ($n = 30$ for all meat products except for steak, for which $n = 32$). The meat samples were collected from Nov 23, 1988, through May 2, 1989. The samples were weighed, chopped finely, packed in aluminum foil pouches, and kept in the dark until analysis.

Chemical Analyses. All the analyses were done in triplicate for each meat sample.

Total iron (TFe) was determined in wet-ashed samples by using ferrozine. Wet ashing involved digesting 1-g aliquots in boiling concentrated nitric acid until the solution was clear and all yellow fumes were dissipated. Then, several drops of 30% hydrogen peroxide was added to each sample and heating was continued until a white ash remained. The ash was dissolved in 6 N hydrochloric acid and diluted to 5 mL with deionized water. To 1 mL of neutralized ash solution (pH adjusted to 8 with 12 N NH_4OH) was added 1 mL of 10% hydroxylamine hydrochloride and the solution was mixed and allowed to stand for 15 min. To this was added 1 mL of 10% ammonium acetate, the solution was mixed, and 1 mL of 1 μM ferrozine was added. The volume was made to 5 mL, and the solution was mixed and left to stand in the dark for 45 min. The absorbance was determined at 562 nm, and the concentration of total iron in the samples was determined against reference standards. With each batch of meat samples, duplicate samples of the National Institute of Science and Technology (NIST, formerly the National Bureau of Standards) bovine liver (1577a) and wheat flour (1567) standard reference materials (SRMs) were analyzed for total iron as a control for total iron determination. Across all batches, analyzed values for the bovine liver and wheat flour SRMs averaged (mean ± SD) 202 ± 11.8 and 19 ± 1.7 μg/g, respectively, as compared with certified values of 193 ± 20 and 18.3 ± 1.0 μg/g, respectively.

Heme iron (HFe) was determined in acid–acetone extracts of the samples by the Hornsey (1956) method. Approximately 10-g aliquots were made into a smooth paste with 10 mL of acid–acetone mixture (40 mL of acetone, 4 mL of water, and 1 mL of concentrated hydrochloric acid). Then, an additional 35 mL of acid–acetone mixture was added, and the contents were mixed well and kept in the dark for 1 h. The extract was centrifuged at 2200g at 10 °C for 10 min. The supernatant was filtered through glass microfiber filters (Whatman GF/A). This gave a solution of acid hematin in 80% acid–acetone. Total heme pigment was measured at 640 nm. Total heme as hematin in each sample was calculated as follows:

$$\text{hematin, g} = \text{OD at } 640_{\text{nm}} \times 680 \text{ (extinction coefficient)} \times \text{aliquot wt, g}/10$$

The HFe content in each sample was then computed by assuming that hematin contains 88.2 mg of iron/g as follows:

$$\text{HFe, } \mu\text{g/g} = (\text{hematin, g} \times 88.2 \text{ mg Fe/g}) \div \text{aliquot wt, g}$$

Nonheme iron (NHFe) content of each aliquot was computed as the difference between TFe and HFe as follows:

$$\text{NHFe, } \mu\text{g/g} = \text{TFe, } \mu\text{g/g} - \text{HFe, } \mu\text{g/g}$$

Percentage heme iron (HFe%) was calculated as follows:

$$\text{HFe\%} = (\text{HFe, } \mu\text{g/g} \div \text{TFe, } \mu\text{g/g}) \times 100$$

Percentage dry matter (DM%) in the meat samples was determined on 2-g aliquots by lyophilizing to constant weight (24 h) in a freeze dryer with shelf temperature set at 40 °C.

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Table I. Total Iron (TFe), Heme Iron (HFe), Nonheme Iron (NHFe), Percent Heme Iron (HFe%), and Dry Matter (DM) in Beef Steak, Beef Burger, Roast Beef, and Frankfurters from Different Sources

sources	TFe[a]	HFe[a]	NHFe[a]	HFe%	DM%
beef steak[b]					
1	39.2	25.0	14.2	63.9	38.8
2	39.1	20.8	18.4	52.1	38.6
3	27.6	17.5	10.1	63.5	39.6
4	30.7	20.8	9.9	67.2	41.2
overall mean ± SE	34.2 ± 1.4	21.0 ± 1.0	13.1 ± 0.7	61.7 ± 1.4	39.6 ± 0.8
beef burger[c]					
1	34.9	22.1	12.8	63.3	46.8
2	30.5	12.0	10.5	65.9	50.6
3	34.2	21.9	12.3	64.0	47.2
4	32.1	19.1	13.0	59.4	48.0
5	27.7	17.3	10.4	62.8	44.0
6	29.5	19.7	9.8	67.3	49.8
overall mean ± SE	31.5 ± 0.6	20.0 ± 0.4	11.4 ± 0.4	63.8 ± 1.0	47.7 ± 0.6
roast beef[d]					
1	29.5	13.4	16.1	45.5	39.3
2	26.1	13.9	12.2	53.3	40.3
3	36.2	18.6	17.6	51.4	30.3
4	36.3	17.1	19.3	47.0	26.3
5	32.9	20.7	12.2	63.0	42.3
6	37.6	17.9	19.7	47.9	27.7
7	33.1	15.1	18.0	46.0	30.3
8	29.6	14.6	14.9	49.6	25.0
9	38.9	19.5	19.4	50.1	35.0
10	36.0	16.3	19.7	45.3	27.7
overall mean ± SE	33.6 ± 1.0	16.8 ± 0.5	16.8 ± 0.7	50.2 ± 1.1	32.6 ± 1.2
frankfurters[e]					
1	25.5	8.6	16.7	33.9	43.8
2	37.6	13.1	24.5	34.9	47.5
3	31.0	9.4	21.6	30.0	47.6
overall mean ± SE	31.4 ± 1.1	10.4 ± 0.5	21.0 ± 0.7	33.0 ± 0.8	46.3 ± 1.3

[a] Micrograms per gram on fresh weight basis. [b] Each value is a mean of 8 samples analyzed in triplicate. [c] Each value is a mean of 5 samples analyzed in triplicate. [d] Each value is a mean of 3 samples analyzed in triplicate. [e] Each value is a mean of 10 samples analyzed in triplicate.

Table II. Mean Square and *F* (in Parentheses) Values for Effects of Meat, Source of Meat, and Replication of Samples on Iron Contents in Selected Meat Foods[a]

		mean square (*F*) values				
source	df	TFe	HFe	NHFe	HFe%	DM%
meat	3	75.6 (0.64[NS])	342.7 (6.73)[b]	251.0 (8.09)[b]	3088 (27.7)[b]	1073 (15.1)[b]
source/meat	19	117.7 (6.02)[b]	50.9 (8.49)[b]	31.0 (3.12)[b]	111.4 (4.85)[b]	71.1 (3.07)[b]
replicates/source	99	19.6	6.0	9.9	23.0	23.1

[a] Meat foods are beef burger, frankfurter, beef steak, and roast beef. NS, not statistically significant. [b] Values carrying the same superscript within rows are significant at $p < 0.01$.

Statistical Analysis. The data were analyzed by using an unbalanced nested analysis of variance (Steel and Torrie, 1980) with four meats (30 replicate samples of beef burger, frankfurter, and roast beef and 32 replicates of beef steak) selected from 3 to 10 sources (frankfurter 3, beef steak 4, beef burger 6, and roast beef 10).

RESULTS AND DISCUSSION

The objective of this study was to determine the heme iron content of different ready-to-serve meat products. It is important that correct estimates of food heme iron and nonheme iron content be available for accurate prediction of absorbable dietary iron. TFe, HFe, NHFe, and HFe% contents of beef steak, beef burger, roast beef, and frankfurter are presented in Table I. TFe contents were similar among the different meat products. A comparison of the mean TFe values for meats in this study with published values (Richardson et al., 1980; Anderson et al., 1986) leads to some interesting similarities and variations. TFe for beef steak in this study (Table I) is similar to 35.8 μg of Fe/g (for beef, short loin, tenderloin, separable lean only, prime cooked, broiled) reported by Anderson et al. (1986). The TFe values for beef burger, roast beef, and frankfurters are higher than the respective reported values of 24.5 μg of Fe/g (for beef, ground, lean, cooked, boiled, well done; Anderson et al., 1986), 29.4 μg of Fe/g (for beef, round, separable lean only, all grades, cooked, roasted; Anderson et al., 1986), and 13.2 ± 0.3 μg of Fe/g (for frankfurter, beef; Richardson et al., 1980). We have no explanation for the differences in TFe found in this study as compared with reported TFe values, especially for frankfurters. In this study, analyzed TFe values for NIST bovine liver and wheat flour were consistently within the certified values for these SRMs which were analyzed with each batch of the different meat samples. About 6 months after completing the frankfurter TFe analyses, we analyzed another batch of three frankfurter samples, and these TFe values also averaged 33.0 μg of Fe/g. We therefore feel that the meat TFe values in this study are accurate.

The HFe contents of ready-to-serve beef burger, frankfurter, beef steak, and roast beef are presented in Table I. The frankfurter HFe level is similar to the 9.1 ± 0.8 μg of Fe/g (mean ± SE) reported by Hendricks et al. (1987) on six frankfurter and bologna samples. Jansuittivechakul et al. (1985) reported 58.3 μg/g of heme iron in lyophilized beef round, baked medium (roast beef), which is similar to the 51.4 μg/g dry matter obtained in this study.

HFe% values for ready-to-serve beef burger, frankfurter, beef steak, and roast beef sampled from various sources (Table I) are similar to published values. Martínez-Torres et al. (1986) reported HFe% values of 55, 53, and 58%, respectively, for burger, steak, and roast beef. Cook and Monsen (1976), Field et al. (1980), Schricker et al. (1982), Jansuittivechakul et al. (1985), and Buchowski et al. (1988) reported that HFe% ranged from 50 to 60% in beef. In all of the studies cited above, small numbers of samples were analyzed and the methods of meat preparation were highly variable.

NHFe contents varied among the meats; it is high for frankfurters and roast beef as compared with beef burger and beef steak (Table I). Igene et al. (1979), Buchowski et al. (1988), and King et al. (1990) demonstrated that nonheme iron is increased and heme iron is decreased due to heating. It is customary to heat-process frankfurter and roast beef for a longer time, which may account for the increase in NHFe and decrease in HFe% of these products as compared with burger and steak.

One objective of this study was to examine popular meat foods for TFe and HFe%. Table II provides mean squares and F values from the analysis of variance for estimates of different iron forms. Mean TFe, HFe, NHFe, HFe%, and DM% were significantly different ($p < 0.01$) among meat foods and their sources. However, replication mean squares were low for all parameters, indicating that sample variation within a source was relatively small.

From this study, it is clear that red meat has a high level of heme iron and therefore can be expected to contribute much absorbable iron to diets. From this study, burger and steak contain at least 60% heme iron. Because the bioavailability of heme iron is high (23%) as compared with nonheme iron (2–8%) (Monsen et al., 1978), more research on heme content and HFe% in a variety of meat, poultry, and fish products is being conducted to accurately estimate the absorbable dietary iron contributions of these foods.

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