



## CHAPTER III

### RESULTS

#### 1. Iron Contents of Meat

Means of iron contents in various meat are shown in Tables 1, 2, 3 and 4. Statistical data are listed in Appendix A.

##### 1.1 Beef

Round and tenderloin were not significantly different in total, nonheme and soluble iron contents but their heme iron contents, 27.42 and 22.71  $\mu\text{g/g}$  for round and tenderloin, were significantly different ( $P < 0.05$ ). Iron content of heart was similar to those of round and tenderloin while the highest iron contents in total, heme, nonheme and soluble forms were found 122.28, 51.53, 70.76 and 7.22  $\mu\text{g/g}$ , respectively, in liver (Tables 1 and 2).

##### 1.2 Pork

Total, heme and nonheme iron contents of round and tenderloin were not significantly different (Tables 1 and 2). The values were lower than those of heart which were 57.98, 24.88 and 33.10  $\mu\text{g/g}$ , respectively ( $P < 0.05$ ). Contents of these iron forms in liver (214.37, 28.95 and 185.42  $\mu\text{g/g}$ , respectively) were the highest when compared with those of round, tenderloin and heart. However, soluble iron contents of round, tenderloin, liver and

**TABLE 1.** Heme and Nonheme Iron Contents of Meat, Liver and Heart of Cow, Pig and Chicken<sup>1,2</sup>

	Iron Content ( $\mu\text{g/g}$ wet weight)	
	Heme Iron	Nonheme Iron
<b>Beef</b>		
round	27.42 $\pm$ 2.06 <sup>a</sup>	14.22 $\pm$ 4.83 <sup>i</sup>
tenderloin	22.71 $\pm$ 7.12 <sup>b</sup>	20.06 $\pm$ 5.18 <sup>ij</sup>
liver	51.53 $\pm$ 15.07 <sup>c</sup>	70.76 $\pm$ 42.12 <sup>k</sup>
heart	27.15 $\pm$ 1.14 <sup>a</sup>	25.28 $\pm$ 1.79 <sup>j</sup>
<b>Pork</b>		
round	6.85 $\pm$ 2.61 <sup>d</sup>	4.67 $\pm$ 0.65 <sup>l</sup>
tenderloin	3.24 $\pm$ 0.61 <sup>d</sup>	5.58 $\pm$ 1.15 <sup>l</sup>
liver	28.95 $\pm$ 4.55 <sup>e</sup>	185.42 $\pm$ 30.80 <sup>m</sup>
heart	24.88 $\pm$ 7.10 <sup>f</sup>	33.10 $\pm$ 13.67 <sup>n</sup>
<b>Chicken</b>		
leg	3.48 $\pm$ 0.43 <sup>g</sup>	7.93 $\pm$ 2.33 <sup>o</sup>
breast	1.27 $\pm$ 0.18 <sup>g</sup>	11.70 $\pm$ 1.74 <sup>op</sup>
liver	18.56 $\pm$ 2.73 <sup>h</sup>	80.73 $\pm$ 8.31 <sup>q</sup>
heart	15.83 $\pm$ 2.58 <sup>h</sup>	21.16 $\pm$ 12.51 <sup>p</sup>

<sup>1</sup>values present means  $\pm$  S.D.; 5 determinations.

<sup>2</sup>values followed by different superscripts within a column are statistically different at  $P < 0.05$ .

**TABLE 2. Total and Soluble Iron Contents of Meat, Liver and Heart of Cow, Pig and Chicken<sup>1,2</sup>**

	Iron Content ( $\mu\text{g/g}$ wet weight)	
	Total Iron	Soluble Iron <sup>3</sup>
<b>Beef</b>		
round	41.63 $\pm$ 4.23 <sup>a</sup>	2.50 $\pm$ 0.88 <sup>i</sup>
tenderloin	42.77 $\pm$ 4.98 <sup>a</sup>	3.08 $\pm$ 1.05 <sup>i</sup>
liver	122.28 $\pm$ 46.56 <sup>b</sup>	7.22 $\pm$ 1.93 <sup>j</sup>
heart	52.43 $\pm$ 2.77 <sup>a</sup>	2.20 $\pm$ 0.35 <sup>i</sup>
<b>Pork</b>		
round	11.52 $\pm$ 2.35 <sup>c</sup>	4.02 $\pm$ 0.95 <sup>kl</sup>
tenderloin	8.82 $\pm$ 1.47 <sup>c</sup>	3.09 $\pm$ 0.90 <sup>k</sup>
liver	214.37 $\pm$ 34.29 <sup>d</sup>	4.61 $\pm$ 2.05 <sup>l</sup>
heart	57.98 $\pm$ 19.66 <sup>e</sup>	4.37 $\pm$ 1.42 <sup>l</sup>
<b>Chicken</b>		
leg	11.41 $\pm$ 2.51 <sup>f</sup>	1.32 $\pm$ 0.51 <sup>m</sup>
breast	12.96 $\pm$ 1.69 <sup>f</sup>	0.70 $\pm$ 0.17 <sup>m</sup>
liver	99.19 $\pm$ 10.83 <sup>g</sup>	16.20 $\pm$ 3.42 <sup>n</sup>
heart	36.99 $\pm$ 12.46 <sup>h</sup>	3.07 $\pm$ 2.38 <sup>o</sup>

<sup>1</sup> values represent means  $\pm$  S.D.; 5 determinations.

<sup>2</sup> values followed by different superscripts within a column are statistically different at  $P < 0.05$ .

<sup>3</sup> [soluble iron] = [total iron in water extract of meat]

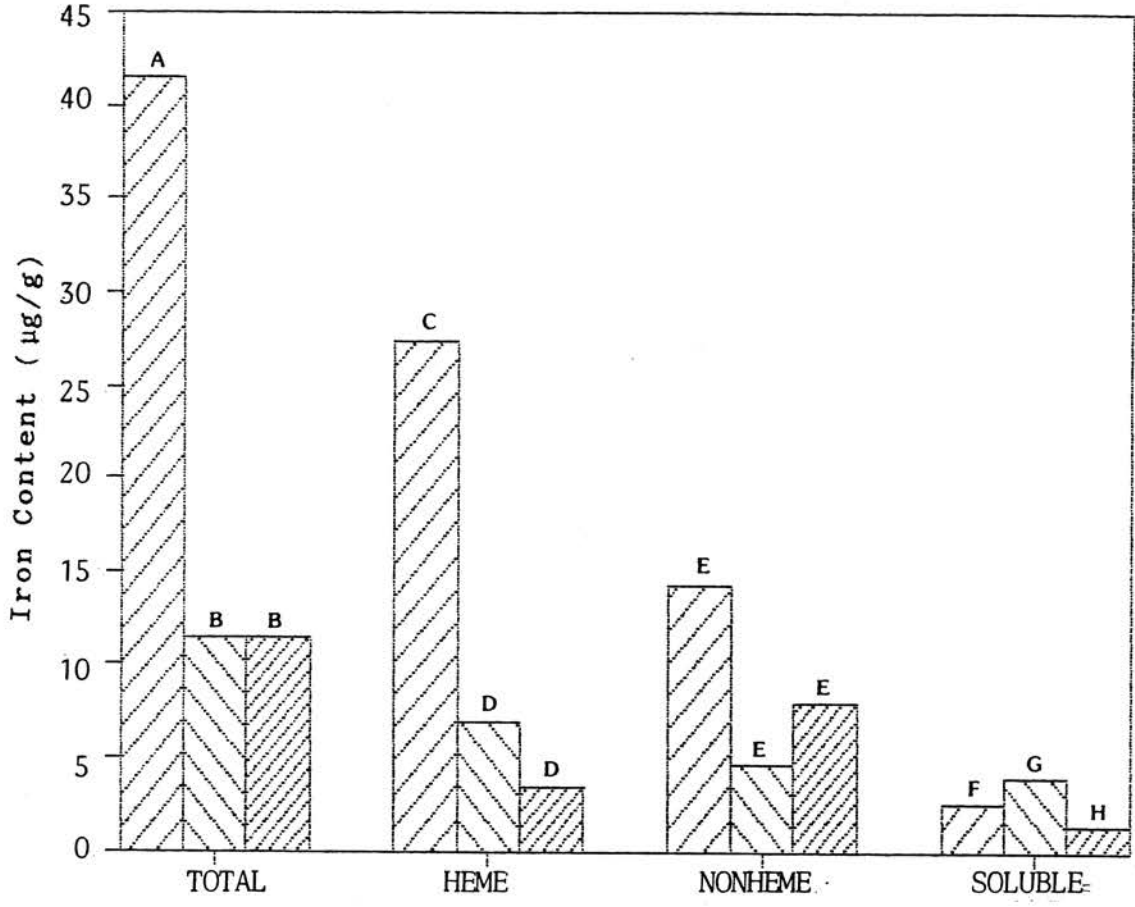
heart (4.02, 3.09, 4.61 and 4.37  $\mu\text{g/g}$ , respectively) were slightly different.

### 1.3 Chicken

Contents of iron found in leg, breast, liver and heart of chicken are shown in Tables 1 and 2. The contents of different iron forms of leg and breast were not significantly different ( $P>0.05$ ) but were significantly lower than those of liver and heart. Heme iron contents of liver and heart (18.56 and 15.83  $\mu\text{g/g}$ , respectively) were not statistically significantly different but the other iron contents of heart were lower than those of liver ( $P<0.05$ ).

### 1.4 Red Meat

Iron contents of beef round, pork round and chicken leg which are red meat are shown in Figure 3. Total and heme iron contents of beef round, 41.63 and 27.42  $\mu\text{g/g}$ , were higher than those of pork round, 11.52 and 6.85  $\mu\text{g/g}$ , and chicken leg, 11.41 and 3.48  $\mu\text{g/g}$ . However, these iron contents of pork round and chicken leg were not significantly different ( $P>0.05$ ). Nonheme iron contents of beef round, pork round and chicken leg (14.22, 4.67 and 7.93  $\mu\text{g/g}$ , respectively) were not statistically significantly different. Soluble iron content found in pork round, beef round and chicken leg were 4.02, 2.50 and 1.32  $\mu\text{g/g}$ , respectively.



**Figure 3. Iron Contents of Red Meat**

▨ beef round; ▩ pork round; ▧ chicken leg

Bars with different superscripts are significantly different at P<0.05.

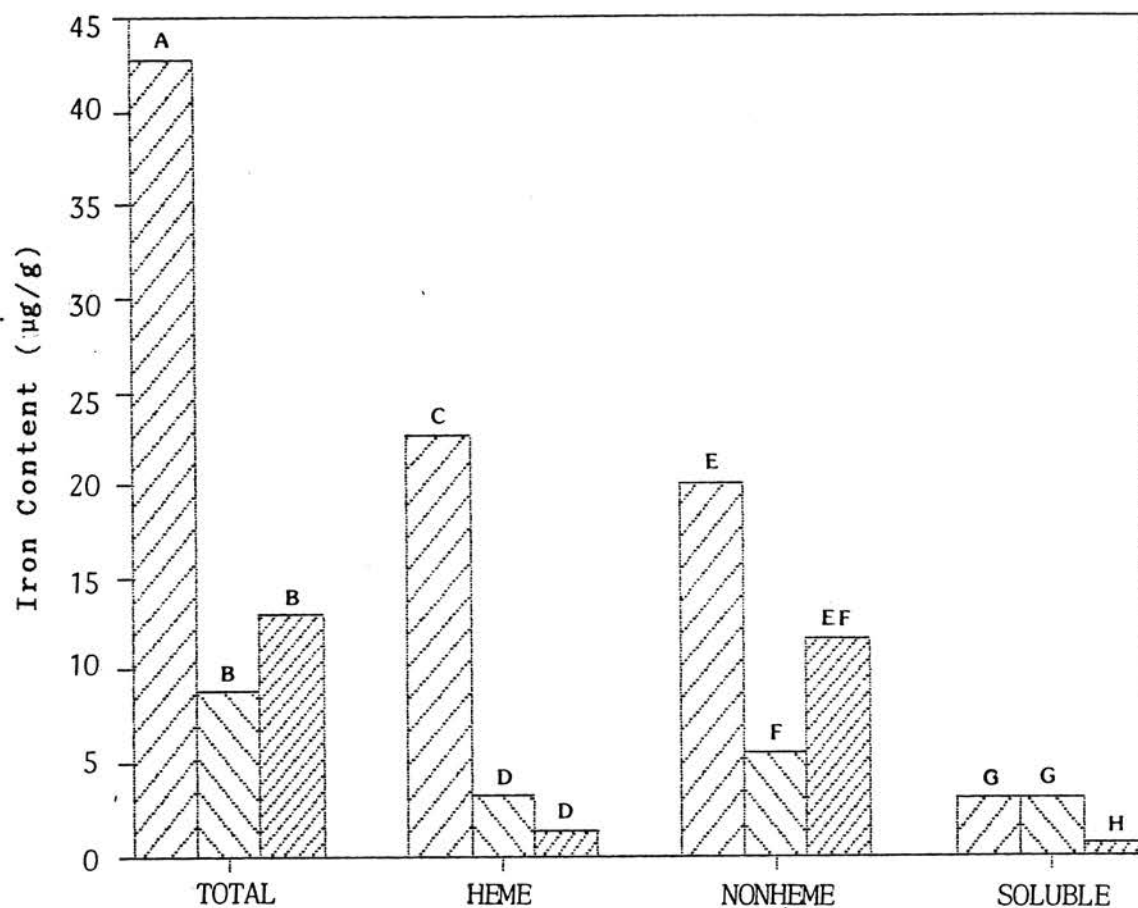


### 1.5 White Meat




Iron contents of white meat such as beef tenderloin, pork tenderloin and chicken breast are graphically presented in Figure 4. Total iron content of beef tenderloin, 42.77  $\mu\text{g/g}$ , was the highest compared with pork tenderloin and chicken breast. The iron contents of pork tenderloin (8.82  $\mu\text{g/g}$ ) and chicken breast (12.96  $\mu\text{g/g}$ ) were not statistically significantly different. Heme and nonheme iron contents of beef tenderloin, 22.71 and 20.06  $\mu\text{g/g}$ , were higher than those of pork tenderloin, 3.24 and 5.58  $\mu\text{g/g}$  which were not statistically significantly different from those of chicken breast, 1.27 and 11.70  $\mu\text{g/g}$ . Soluble iron content of chicken breast, 0.70  $\mu\text{g/g}$ , was the lowest compared with those of beef tenderloin and pork tenderloin, 3.08 and 3.09  $\mu\text{g/g}$ .

### 1.6 Liver

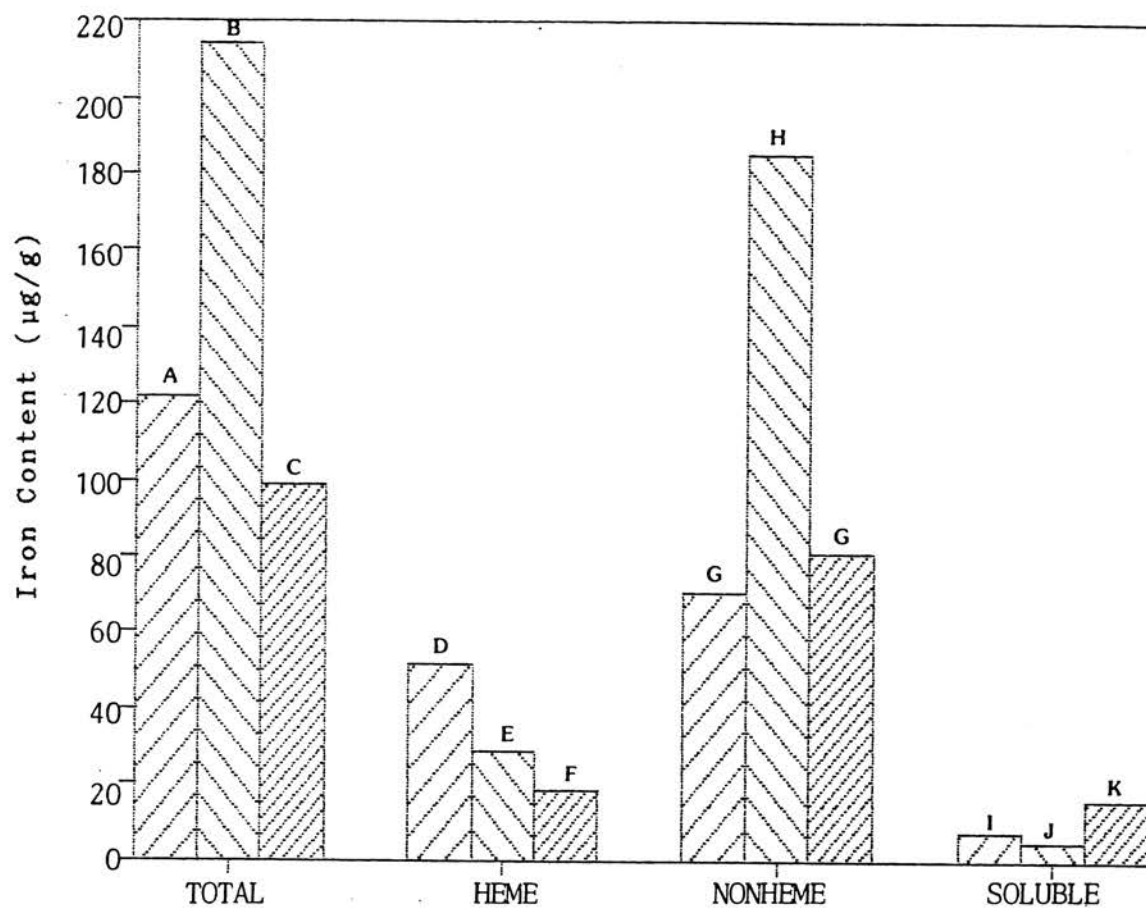
The highest level of total iron, 214.37  $\mu\text{g/g}$ , was found in pork liver while the levels of beef liver and chicken liver were 122.28 and 99.19  $\mu\text{g/g}$ , respectively (Figure 5). Beef liver contained higher heme iron content than did either pork liver or chicken liver. Nonheme iron content of pork liver, 185.42  $\mu\text{g/g}$ , was higher than those of beef liver and chicken liver, 70.76 and 80.73  $\mu\text{g/g}$ , which were not statistically significantly different ( $P>0.05$ ). The highest level of soluble iron, 16.20  $\mu\text{g/g}$ , was found in chicken liver and the level of beef liver, 7.22  $\mu\text{g/g}$ , was significantly higher than that of pork



**Figure 4. Iron Contents of White Meat**

 beef tenderloin; 
  pork tenderloin; 
  chicken breast

Bars with different superscripts are significantly different at  $P < 0.05$ .



**Figure 5.** Iron Contents of Liver

▨ beef liver; ▤ pork liver; ▥ chicken liver

Bars with different superscripts are significantly different at  $P < 0.05$ .



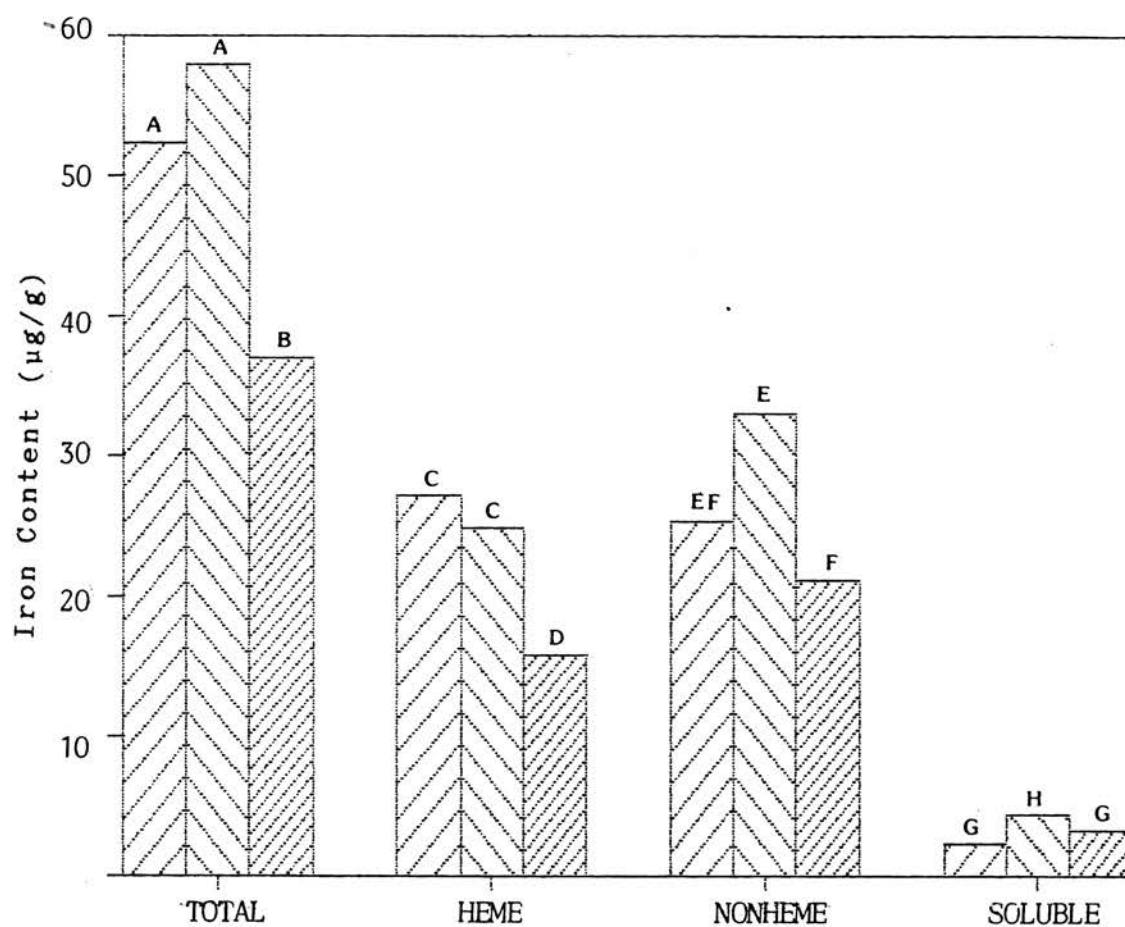
liver, 4.61  $\mu\text{g/g}$  ( $P < 0.05$ ).

### 1.7 Heart

Iron contents of hearts of cow, pig and chicken are graphically presented in Figure 6. Beef heart and pork heart were not statistically significantly different in total and heme iron contents ( $P > 0.05$ ). The total and heme iron contents were 52.43 and 27.15  $\mu\text{g/g}$  for beef heart and 57.98 and 24.88  $\mu\text{g/g}$  for pork heart while the contents of chicken heart were only 36.99 and 15.83  $\mu\text{g/g}$ , respectively. Nonheme and soluble iron contents of chicken heart (21.16 and 3.07  $\mu\text{g/g}$ ) were not statistically significantly different from those of beef heart (25.28 and 2.20  $\mu\text{g/g}$ ) but were lower than those of pork heart (33.10 and 4.37  $\mu\text{g/g}$ )

### 1.8 Fish, Mussel and Shrimp

Snake-head fish and Indo-Pacific mackerel were not statistically significantly different in total iron content but the latter contained higher heme and soluble iron contents than did the former (Tables 3 and 4). Heme and soluble iron contents were 0.50 and 0.86  $\mu\text{g/g}$  for snake-head fish and 4.51 and 2.80  $\mu\text{g/g}$  for Indo-Pacific mackerel. Total, heme and nonheme iron levels of green mussel (90.93, 33.34 and 57.59  $\mu\text{g/g}$ , respectively) were higher than those of fish and banana shrimp ( $P < 0.05$ ). Soluble iron level of green mussel, 3.85  $\mu\text{g/g}$ , was not statistically significantly different from that of Indo-Pacific mackerel but was higher than those of snake-head



**Figure 6. Iron Contents of Heart**

▨ beef heart; ▩ pork heart; ▤ chicken heart

Bars with different superscripts are significantly different at  $P < 0.05$ .

**TABLE 3.** Heme and Nonheme Iron Contents of Fish, Mussel, Shrimp and Cooked Blood<sup>1,2</sup>

=====		
Iron Content ( $\mu\text{g/g}$ wet weight)		
	Heme Iron	Nonheme Iron
-----		
Snake-head fish	0.50 $\pm$ 0.22 <sup>a</sup>	18.41 $\pm$ 2.28 <sup>d</sup>
Indo-Pacific mackerel	4.51 $\pm$ 0.59 <sup>b</sup>	6.05 $\pm$ 1.39 <sup>e</sup>
Green mussel	33.34 $\pm$ 2.64 <sup>c</sup>	57.59 $\pm$ 6.13 <sup>f</sup>
Banana shrimp	0.44 $\pm$ 0.08 <sup>a</sup>	3.58 $\pm$ 0.40 <sup>e</sup>
Cooked pork blood	142.33 $\pm$ 9.85	19.46 $\pm$ 7.69
Cooked chicken blood	80.67 $\pm$ 7.96	19.32 $\pm$ 4.28
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<sup>1</sup> values present means  $\pm$  S.D.; 5 determinations.

<sup>2</sup> values followed by different superscripts within a column are statistically different at  $P < 0.05$ .

**TABLE 4.** Total and Soluble Iron Contents of Fish, Mussel, Shrimp and Cooked Blood<sup>1,2</sup>

	Iron Content ( $\mu\text{g/g}$ wet weight)	
	Total Iron	Soluble Iron <sup>3</sup>
Snake-head fish	18.91 $\pm$ 2.46 <sup>a</sup>	0.86 $\pm$ 0.27 <sup>d</sup>
Indo-Pacific mackerel	10.55 $\pm$ 1.48 <sup>ab</sup>	2.80 $\pm$ 0.95 <sup>e</sup>
Green mussel	90.93 $\pm$ 8.55 <sup>c</sup>	3.85 $\pm$ 0.44 <sup>e</sup>
Banana shrimp	4.02 $\pm$ 0.48 <sup>b</sup>	0.94 $\pm$ 0.59 <sup>d</sup>
Cooked pork blood	161.79 $\pm$ 9.95	4.26 $\pm$ 0.50
Cooked chicken blood	99.94 $\pm$ 10.34	3.23 $\pm$ 1.15

<sup>1</sup> values represent means  $\pm$  S.D.; 5 determinations.

<sup>2</sup> values followed by different superscripts within a column are statistically different at  $P < 0.05$ .

<sup>3</sup> [soluble iron] = [total iron in water extract of meat]

fish and banana shrimp which were 0.86 and 0.94  $\mu\text{g/g}$ , respectively. Total and nonheme iron contents of banana shrimp were similar to those of Indo-Pacific mackerel while its heme and soluble iron contents were similar to those of snake-head fish.

### 1.9 Cooked Blood

Mean iron contents of cooked pork blood and cooked chicken blood are shown in Tables 3 and 4. Total and heme iron contents of cooked pork blood, 161.79 and 142.33  $\mu\text{g/g}$ , were significantly higher than those of cooked chicken blood which were 99.94 and 80.67  $\mu\text{g/g}$ , respectively. However, nonheme and soluble iron contents of these sources were not statistically significantly different ( $P>0.05$ ).

## 2. Effects of Heat Treatments on Meat Iron Content

Heme, nonheme and soluble iron contents of boiled and dried meat expressed as percent of those of raw or fresh meat are shown in Tables 5, 6 and 7, respectively.

### 2.1 Effect on Heme Iron Content

As shown in Table 5, heat treatments resulted in reduction of heme iron levels in various kinds of meat. After boiling for 15, 30 and 60 minutes, heme iron in 16 kinds of meat were retained 88.12%, 81.06% and 74.62% of that of raw meat, respectively, accordingly the reductions were 11.88%, 18.94% and 25.38%, respectively (Table 8). A linear relationship between heme iron content and the

length of boiling time was observed (Figure 7). A regression equation was  $Y = 96.54 - 0.40 X$ , where  $X$  was the length of boiling time and  $Y$  was the heme iron content of boiled meat expressed as a percent of that of raw sample and the corresponding correlation coefficient ( $r$ ) was  $-0.9505$ . Drying (50-60 C, 8 hours) caused 31.82% reduction of heme iron level since heme iron content of dried meat was 68.18% of that of fresh meat.

## 2.2 Effect on Nonheme Iron Content

Effects of boiling and drying on nonheme iron content of meat are shown in Table 6. Nonheme iron contents of meat boiled for 15, 30 and 60 minutes were increased 6.14%, 8.80% and 12.63% of that of raw sample, respectively (Table 8). The nonheme iron content and boiling time were correlated,  $r = 0.9559$  with a linear regression equation  $Y = 101.59 + 0.20 X$ , where  $X$  was the length of boiling time and  $Y$  was the nonheme iron content of boiled meat expressed as a percent of that of raw sample (Figure 8). Drying at 50-60 C for 8 hours resulted in increase of nonheme iron content. Nonheme iron content of dried meat were 16.24% higher than that of fresh meat.

## 2.3 Effect on Soluble Iron Content

Influence of heat treatments upon the level of soluble iron in meat is shown in Table 7. Increases of soluble iron content of meat resulted from boiling for 15, 30 and 60 minutes were 34.04%, 54.59% and 81.42%, respectively (Table 8). A linear relationship between

soluble iron content and the length of boiling time was observed (Figure 9). Correlation coefficient ( $r$ ) was 0.9736 with a regression equation  $Y = 108.25 + 1.31 X$ , where  $X$  was the length of boiling time and  $Y$  was the soluble iron content of boiled meat expressed as a percent of that of raw sample. Furthermore, soluble iron content was substantially increased after drying at 50-60 °C for 8 hours (Table 7). The soluble iron content of dried meat was 185.77% higher than that of fresh sample.

It was observed that increases of soluble iron content in red meat and liver among beef, pork and chicken were statistically significantly different ( $P < 0.05$ ). The elevation of soluble iron content of chicken leg was higher than those of beef round and pork round, respectively (Figure 10). The elevations of soluble iron content of beef liver and chicken liver were lower than that of pork liver (Figure 11). On the other hand, the alterations of soluble iron content of white meat and heart were not significantly different among these three species (Appendix B).

Heat treatments significantly decreased heme iron level but increased nonheme iron levels of meat (Table 8). Boiling for 30 and 60 minutes resulted in increased soluble iron content (Table 7). A linear relationship ( $r = -0.9962$ ) between soluble and heme iron contents of boiled meat was observed and the equation for the regression line was  $Y = 130.88 - 0.32 X$ , where  $X$  and  $Y$

**TABLE 5. Heme Iron Contents of Raw, Boiled and Dried Meat<sup>1</sup>**

	Heme Iron Content ( $\mu\text{g/g}$ dry weight)				
	Raw	Boiled 15 min	Boiled 30 min	Boiled 60 min	Dried <sup>2</sup>
<b>Beef</b>					
round	107.48 (100.00)	99.48 (92.56)	93.31 (86.82)	88.52 (82.36)	66.18 (61.58)
tenderloin	99.59 (100.00)	90.22 (90.59)	86.81 (87.17)	81.05 (81.38)	49.42 (49.62)
liver	222.58 (100.00)	200.44 (90.05)	189.39 (85.09)	177.98 (79.96)	161.56 (72.59)
heart	112.86 (100.00)	112.60 (92.40)	105.30 (86.41)	96.38 (79.10)	73.30 (60.15)
<b>Pork</b>					
round	23.58 (100.00)	19.53 (82.81)	17.37 (73.67)	15.50 (65.72)	12.01 (50.94)
tenderloin	12.56 (100.00)	9.53 (75.85)	7.27 (57.86)	6.37 (50.74)	4.80 (38.23)
liver	128.07 (100.00)	104.56 (81.64)	92.03 (71.86)	83.19 (64.95)	79.11 (61.77)
heart	95.29 (100.00)	81.44 (85.46)	77.91 (81.76)	72.38 (75.96)	80.71 (84.70)

<sup>1</sup> values in parentheses represent heme iron content of boiled or dried sample expressed as percent of that of raw or fresh sample.

<sup>2</sup> dried at 50-60 °C for 8 hours.

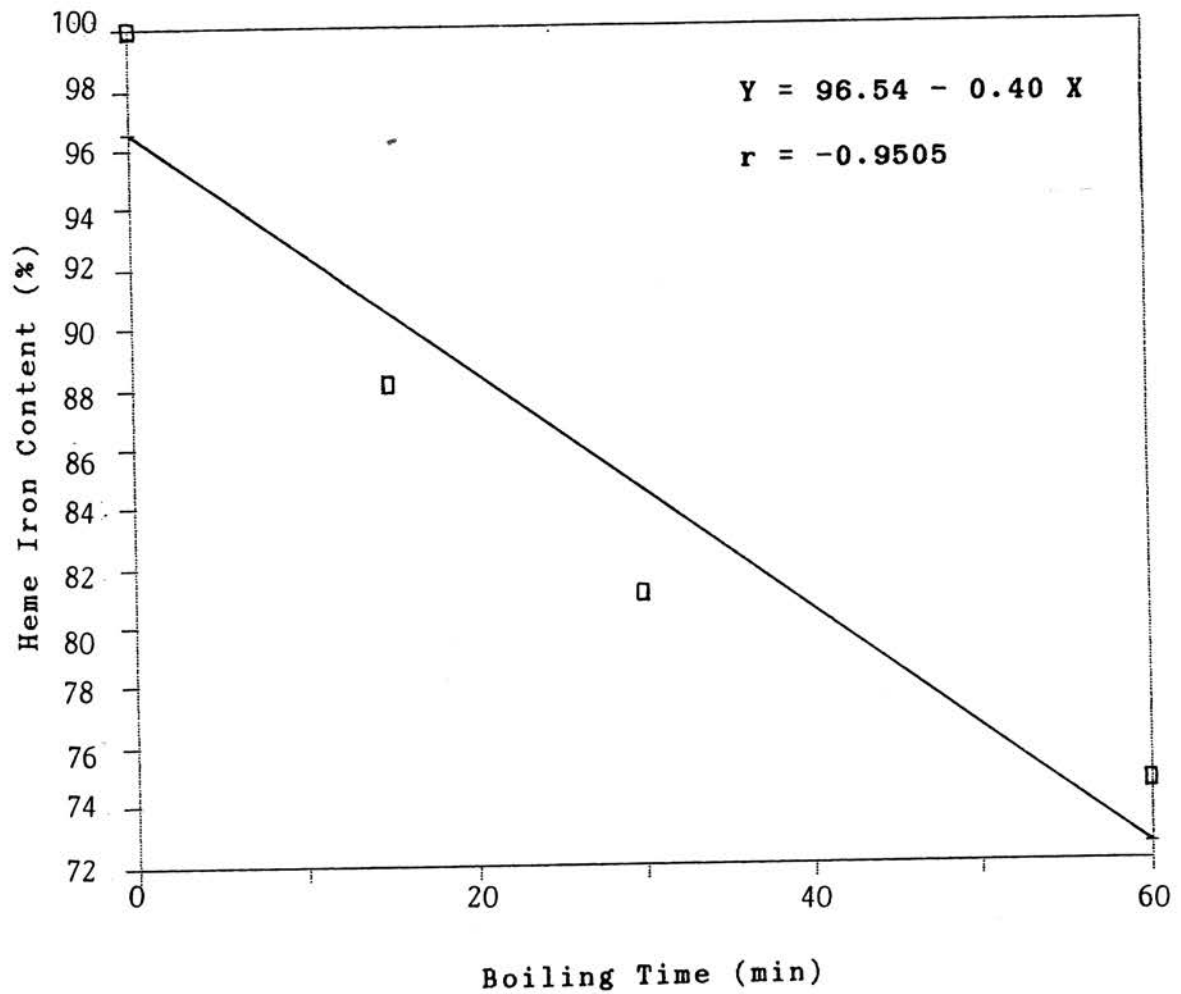


TABLE 5. (continue) Heme Iron Contents of Raw, Boiled  
and Dried Meat<sup>1</sup>

	Heme Iron Content ( $\mu\text{g/g}$ dry weight)				
	Raw	Boiled 15 min	Boiled 30 min	Boiled 60 min	Dried <sup>2</sup>
Chicken					
leg	12.95 (100.00)	10.02 (77.41)	7.82 (60.38)	6.21 (47.92)	5.57 (43.01)
breast	4.78 (100.00)	3.61 (75.65)	2.95 (61.72)	2.62 (54.77)	2.26 (47.36)
liver	70.71 (100.00)	61.93 (87.57)	56.19 (79.45)	50.34 (71.19)	55.15 (77.99)
heart	70.92 (100.00)	65.64 (92.55)	63.37 (89.36)	59.24 (83.53)	61.03 (86.06)
Snake-head fish	3.56 (100.00)	1.67 (46.84)	0.75 (21.09)	0.58 (16.35)	1.26 (35.49)
Indo-Pacific mackerel	21.41 (100.00)	17.63 (82.37)	13.95 (65.18)	10.96 (51.21)	9.27 (43.31)
Green mussel	252.36 (100.00)	222.02 (87.98)	198.04 (78.48)	181.05 (71.74)	189.34 (75.03)
Banana shrimp	2.64 (100.00)	1.21 (45.96)	0.81 (30.86)	0.43 (16.19)	1.30 (49.17)

<sup>1</sup> values in parentheses represent heme iron content of boiled or dried sample expressed as percent of that of raw or fresh sample.

<sup>2</sup> dried at 50-60<sup>o</sup> C for 8 hours.



**Figure 7.** Relationship between Heme Iron Content of Boiled Meat and the Length of Boiling Time

**TABLE 6.** Nonheme Iron Contents of Raw, Boiled and Dried Meat<sup>1</sup>

	Nonheme Iron Content ( $\mu\text{g/g}$ dry weight)				
	Raw	Boiled 15 min	Boiled 30 min	Boiled 60 min	Dried <sup>2</sup>
<b>Beef</b>					
round	63.10 (100.00)	72.62 (115.08)	77.78 (123.25)	83.18 (131.81)	106.29 (168.44)
tenderloin	63.84 (100.00)	73.05 (114.42)	76.09 (119.18)	83.26 (130.42)	114.89 (179.97)
liver	225.17 (100.00)	246.93 (109.66)	255.12 (113.30)	267.51 (118.80)	284.67 (126.43)
heart	113.08 (100.00)	123.89 (109.55)	130.26 (115.19)	138.96 (122.88)	162.80 (143.96)
<b>Pork</b>					
round	25.77 (100.00)	29.01 (112.58)	29.37 (113.98)	33.83 (131.29)	35.74 (138.70)
tenderloin	20.47 (100.00)	24.16 (118.02)	25.19 (123.04)	27.35 (133.61)	29.19 (142.60)
liver	733.81 (100.00)	758.93 (103.42)	767.25 (104.56)	779.28 (106.20)	783.92 (106.83)
heart	146.05 (100.00)	167.15 (114.45)	162.74 (111.43)	172.83 (118.34)	166.23 (113.82)

<sup>1</sup> values in parentheses represent nonheme iron content of boiled or dried sample expressed as percent of that of raw or fresh sample.

<sup>2</sup> dried at 50-60 °C for 8 hours.

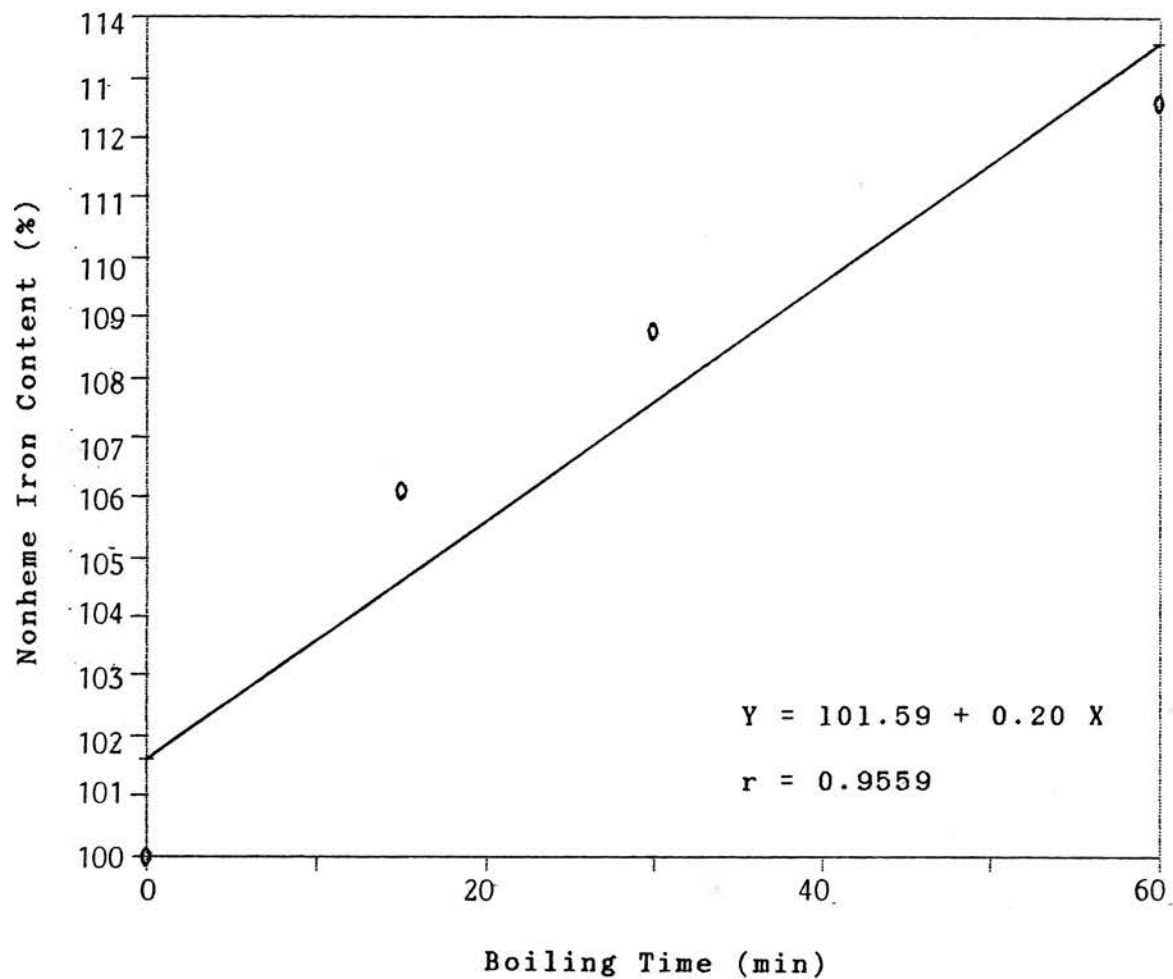


TABLE 6. (continue) Nonheme Iron Contents of Raw, Boiled and Dried Meat<sup>1</sup>

=====					
Nonheme Iron Content ( $\mu\text{g/g}$ dry weight)					
	Raw	Boiled 15 min	Boiled 30 min	Boiled 60 min	Dried <sup>2</sup>
-----					
Chicken					
leg	34.24 (100.00)	35.96 (105.01)	39.42 (115.12)	40.46 (118.16)	42.00 (122.67)
breast	41.87 (100.00)	42.02 (100.37)	42.64 (101.84)	44.43 (106.12)	45.52 (108.74)
liver	288.58 (100.00)	301.73 (104.56)	304.31 (105.45)	308.02 (106.73)	303.11 (105.03)
heart	138.58 (100.00)	147.78 (106.64)	145.24 (104.81)	150.33 (108.48)	145.78 (105.19)
Snake-head fish					
	101.00 (100.00)	99.85 (98.86)	101.67 (100.66)	102.68 (101.66)	104.21 (103.18)
Indo-Pacific mackerel					
	38.69 (100.00)	43.26 (111.81)	48.09 (124.30)	48.76 (126.02)	52.60 (135.94)
Green mussel					
	445.52 (100.00)	464.66 (104.30)	493.11 (110.68)	513.59 (115.28)	507.01 (113.80)
Banana shrimp					
	22.65 (100.00)	25.06 (110.64)	24.95 (110.18)	24.11 (106.47)	24.86 (109.75)
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<sup>1</sup>values in parentheses represent nonheme iron content of boiled or dried sample expressed as percent of that of raw or fresh sample.

<sup>2</sup>dried at 50-60 °C for 8 hours.



**Figure 8.** Relationship between Nonheme Iron Content of Boiled Meat and the Length of Boiling Time

**TABLE 7. Soluble Iron Contents of Raw, Boiled and Dried Meat<sup>1</sup>**

=====					
Soluble Iron Content ( $\mu\text{g/g}$ dry weight)					
	Raw	Boiled 15 min	Boiled 30 min	Boiled 60 min	Dried <sup>2</sup>
-----					
<b>Beef</b>					
round	7.36 (100.00)	9.09 (123.64)	12.50 (169.92)	14.47 (196.73)	22.68 (308.37)
tenderloin	9.21 (100.00)	11.28 (122.49)	12.98 (140.88)	14.71 (159.77)	23.83 (258.72)
liver	32.91 (100.00)	42.93 (130.47)	47.50 (144.35)	45.84 (139.32)	61.29 (186.25)
heart	9.67 (100.00)	13.66 (141.21)	15.75 (162.81)	18.33 (189.50)	36.53 (377.66)
<b>Pork</b>					
round	17.66 (100.00)	20.16 (114.15)	23.73 (134.36)	26.74 (151.40)	33.25 (188.27)
tenderloin	9.03 (100.00)	12.70 (140.62)	14.34 (158.77)	17.37 (192.24)	16.61 (183.85)
liver	12.33 (100.00)	29.89 (242.44)	39.41 (319.69)	74.26 (602.33)	215.50 (1748.02)
heart	12.66 (100.00)	16.40 (129.59)	16.15 (127.64)	17.17 (135.69)	44.82 (354.14)
-----					

<sup>1</sup>values in parentheses represent soluble iron content of boiled or dried sample expressed as percent of that of raw or fresh sample.

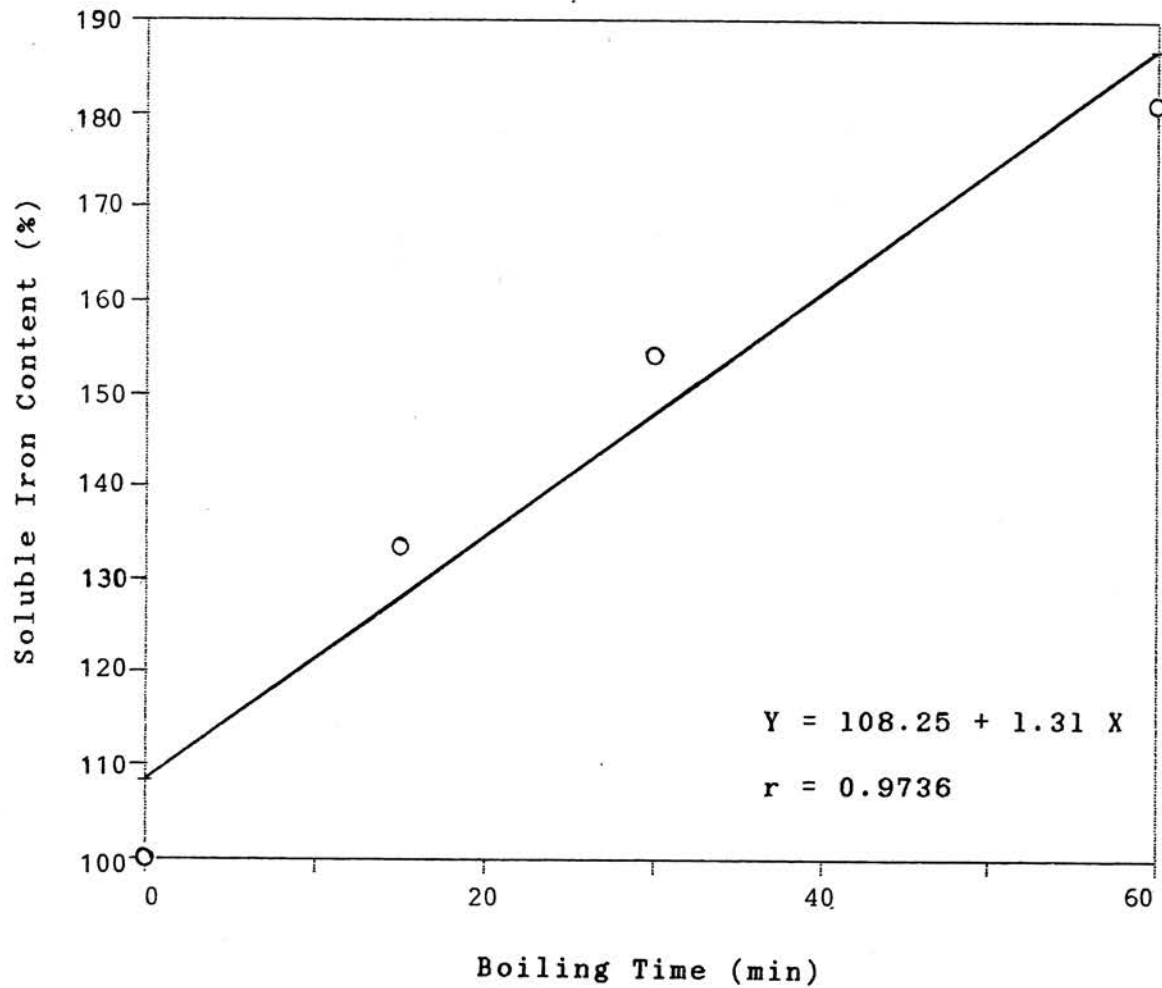
<sup>2</sup>dried at 50-60 °C for 8 hours.

TABLE 7. (continue) Soluble Iron Contents of Raw, Boiled and Dried Meat<sup>1</sup>

	Soluble Iron Content ( $\mu\text{g/g}$ dry weight)				
	Raw	Boiled 15 min	Boiled 30 min	Boiled 60 min	Dried <sup>2</sup>
Chicken					
leg	5.78 (100.00)	8.49 (146.72)	10.82 (187.06)	13.11 (226.73)	10.18 (175.99)
breast	2.12 (100.00)	3.51 (165.53)	4.94 (232.64)	5.40 (254.50)	6.31 (297.40)
liver	53.76 (100.00)	67.38 (125.32)	75.23 (139.92)	78.96 (146.86)	84.71 (157.57)
heart	10.43 (100.00)	12.32 (118.17)	14.15 (135.65)	16.32 (156.49)	22.45 (215.27)
Snake-head fish	4.20 (100.00)	6.20 (147.63)	7.26 (172.93)	7.39 (175.94)	8.75 (208.30)
Indo-Pacific mackerel	15.05 (100.00)	19.30 (128.22)	20.69 (137.42)	24.46 (162.50)	28.06 (186.41)
Green mussel	28.90 (100.00)	36.80 (127.34)	41.84 (144.79)	44.99 (155.69)	46.63 (161.36)
Banana shrimp	3.95 (100.00)	4.89 (123.57)	6.13 (155.00)	6.86 (173.57)	9.99 (252.70)

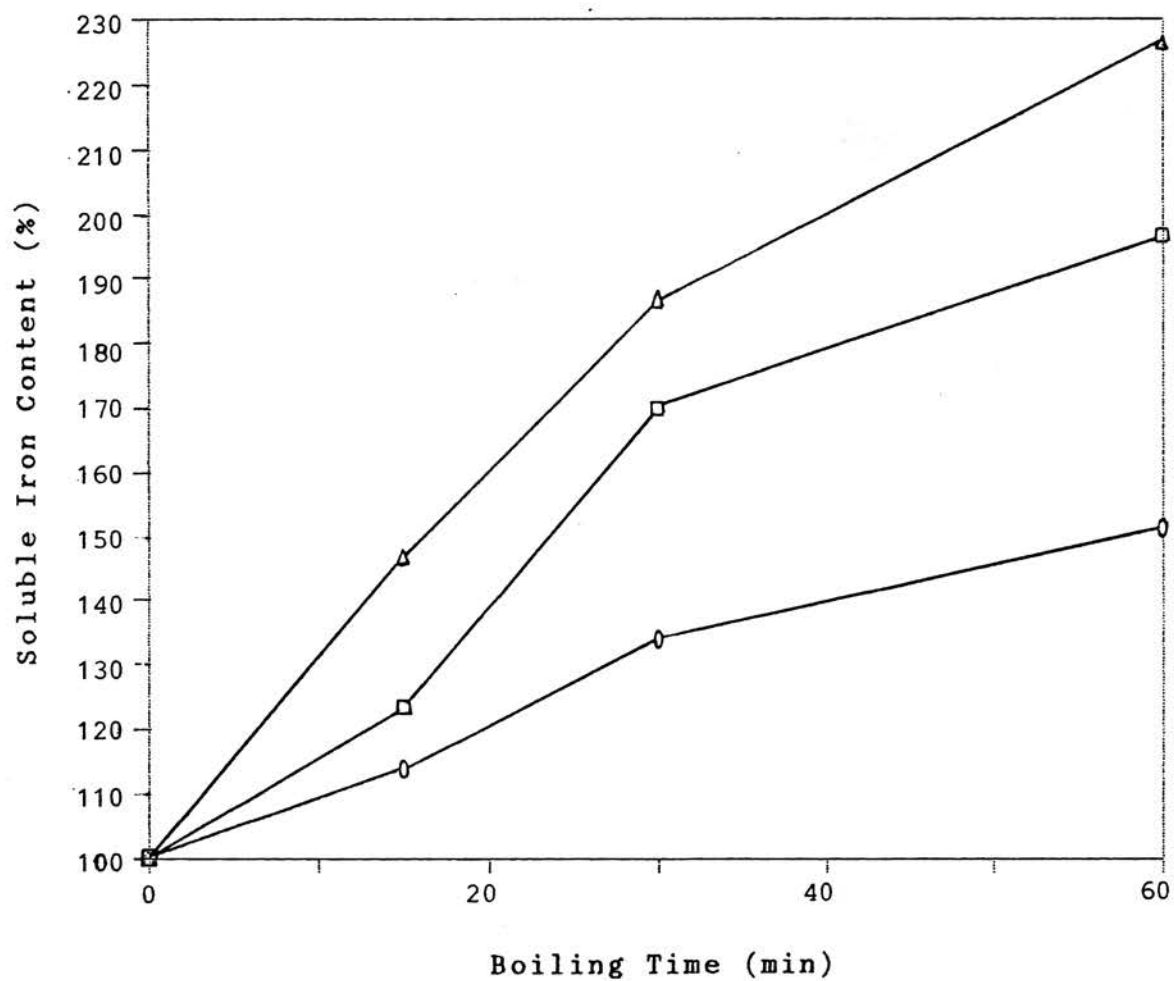
<sup>1</sup> values in parentheses represent soluble iron content of boiled or dried sample expressed as percent of that of raw or fresh sample.

<sup>2</sup> dried at 50-60 C for 8 hours.



**Figure 9.** Relationship between Soluble Iron Content of Boiled Meat and the Length of Boiling Time





**Figure 10.** Effect of Boiling Time on Soluble Iron Content of Red Meat

□, beef round ( $r = 0.9468$ )

○, pork round ( $r = 0.9829$ )

△, chicken leg ( $r = 0.9766$ )

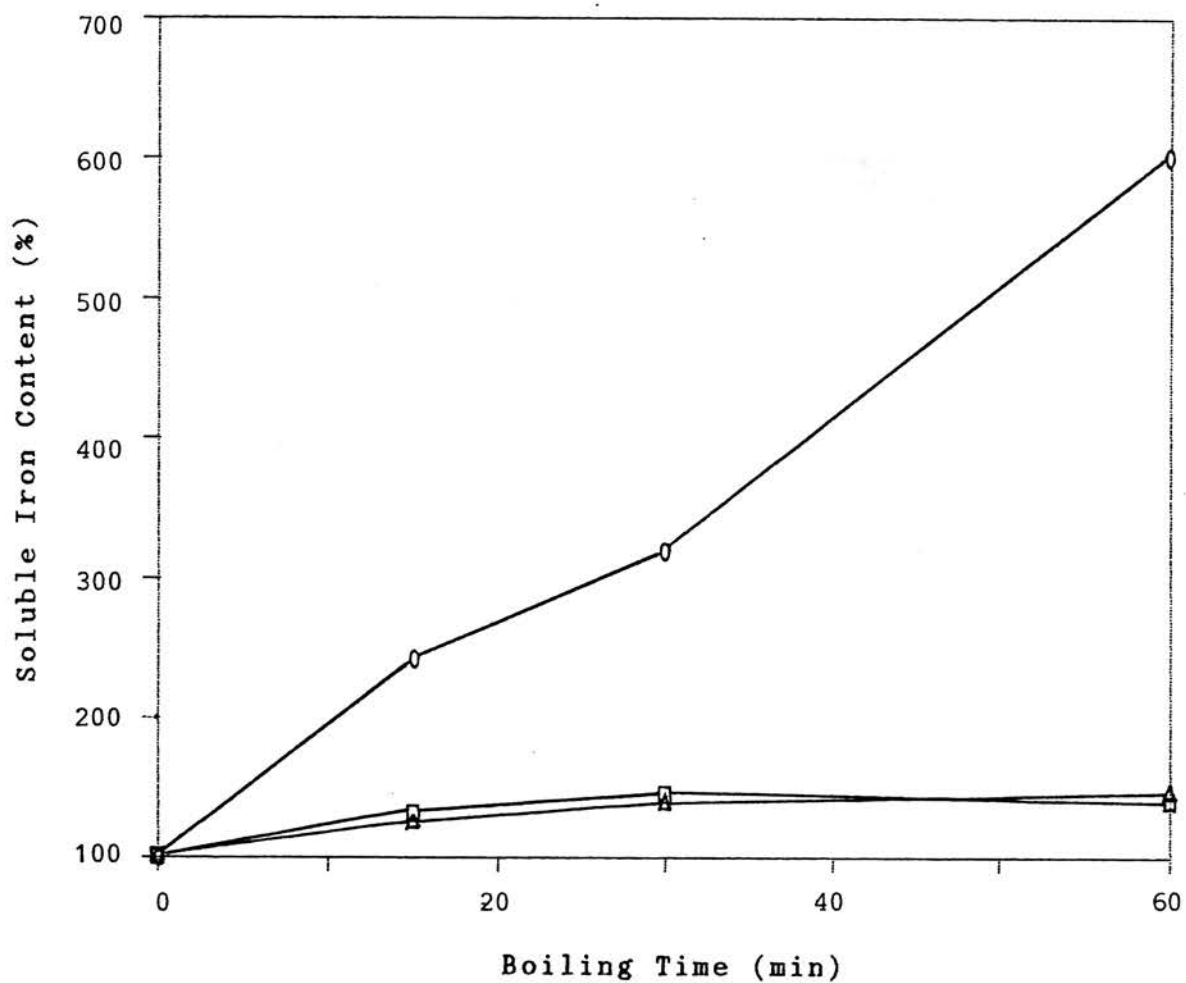


Figure 11. Effect of Boiling Time on Soluble Iron Content of Liver

□, beef liver (r = 0.7535)

○, pork liver (r = 0.9956)

△, chicken liver (r = 0.9080)

TABLE 8. Effects of Boiling and Drying on Different Iron Contents of Meat<sup>1,2,3</sup>

Iron Content (%)	Raw	Boiled 15 min	Boiled 30 min	Boiled 60 min	Dried <sup>4</sup>
Heme Iron	78.13 (100.00)	68.85* (88.12)	63.33* (81.06)	58.30* (74.62)	53.27* (68.18)
Nonheme Iron <sup>5</sup>	156.40 (100.00)	166.00* (106.14)	170.17* (108.80)	176.16* (112.63)	181.80* (116.24)
Soluble Iron <sup>6</sup>	14.69 (100.00)	19.69 (134.04)	22.71 (154.59)	26.65* (181.42)	41.98* (285.77)

<sup>1</sup>values represent average iron contents of 16 kinds of meat as listed in Tables 5, 6 and 7.

<sup>2</sup>values in parentheses represent iron content of boiled or dried sample expressed as percent of that of raw or fresh sample.

<sup>3</sup>asterisks indicate statistical difference calculated with reference to raw or fresh sample at P<0.05.

<sup>4</sup>dried at 50-60<sup>o</sup> C for 8 hours.

<sup>5</sup>[nonheme iron] = [total iron] - [heme iron]

<sup>6</sup>[soluble iron] = [total iron in water extract of meat]

were the soluble and heme iron contents of boiled meat expressed as percent of those of raw sample (Figure 12).

### 3. Effect of Freezing on Meat Iron Content

Influence of freezing upon heme, nonheme and soluble iron levels in meat is shown in Tables 9, 10 and 11, respectively.

#### 3.1 Effect on Heme Iron Content

Heme iron content of frozen meat was not quite different from that of fresh meat (Table 9). After freezing for 1, 2 and 4 weeks, the average contents of heme iron in 16 kinds of meat were 98.74%, 98.10% and 97.94% of that of fresh sample, respectively. The reductions of 1.26%, 1.90% and 2.06% due to freezing for 1, 2 and 4 weeks, respectively, were not statistically significantly ( $P > 0.05$ ) different (Table 12).

#### 3.2 Effect on Nonheme Iron Content

Nonheme iron contents of frozen meat expressed as percent of that of fresh sample are presented in Table 10. Freezing did not significantly change the level of nonheme iron even though the freezing time was up to 4 weeks. Mean nonheme iron contents of meat frozen for 1, 2 and 4 weeks were 100.26%, 101.15% and 101.03% of that of fresh meat, respectively (Table 12).

#### 3.3 Effect on Soluble Iron Content

Soluble iron contents of frozen meat expressed as percent of that of fresh meat are shown in Table 11.

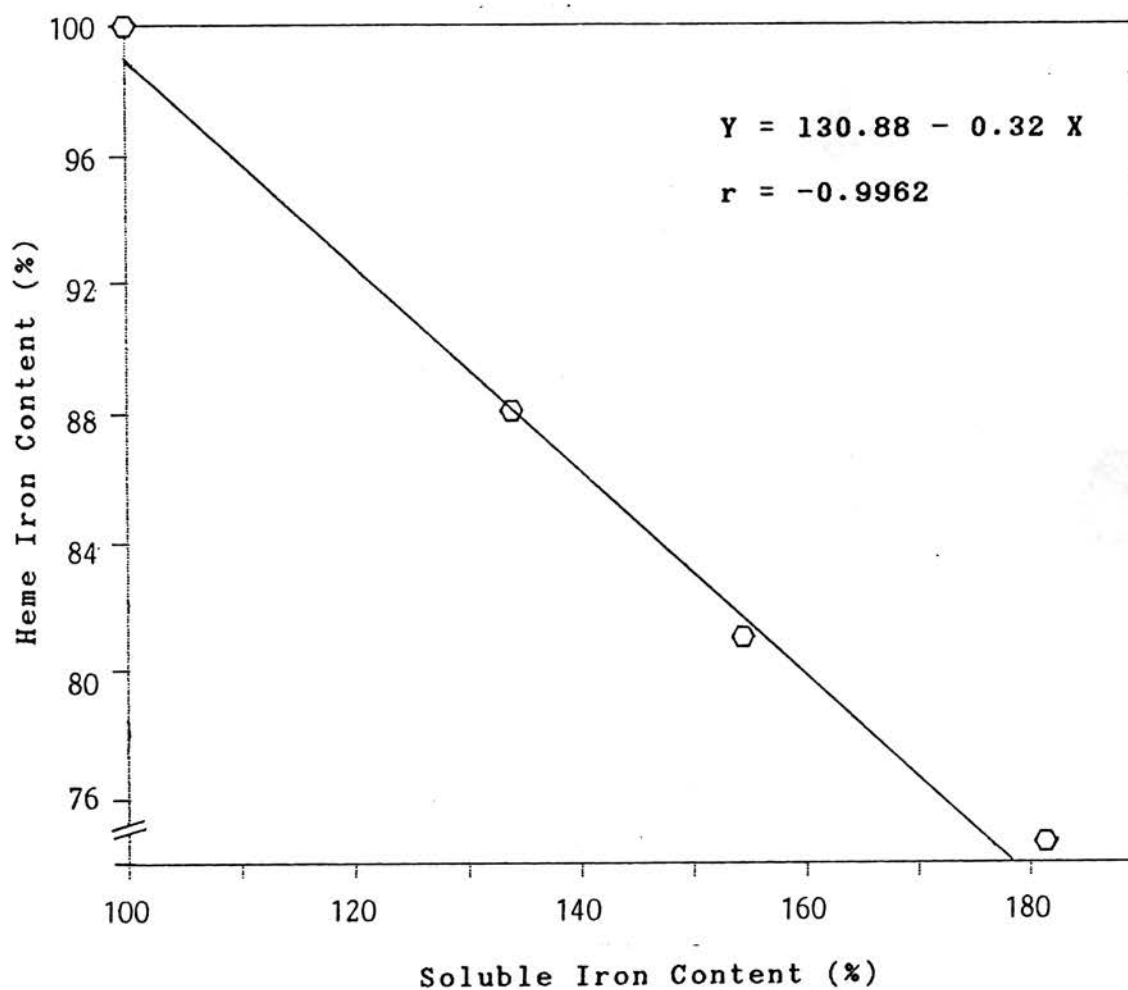


Figure 12. Relationship between Heme Iron and Soluble Iron Contents of Boiled Meat

**TABLE 9. Heme Iron Contents of Fresh and Frozen Meat<sup>1</sup>**

	Heme Iron Content (µg/g dry weight)			
	Fresh	Frozen <sup>2</sup> 1 week	Frozen 2 weeks	Frozen 4 weeks
<b>Beef</b>				
round	107.48 (100.00)	106.28 (98.89)	106.46 (99.05)	105.96 (98.59)
tenderloin	99.59 (100.00)	99.16 (99.56)	98.50 (98.90)	97.69 (98.09)
liver	222.58 (100.00)	216.62 (97.32)	215.16 (96.67)	215.84 (96.97)
heart	121.86 (100.00)	122.31 (100.37)	122.47 (100.51)	121.18 (99.45)
<b>Pork</b>				
round	23.58 (100.00)	22.97 (97.43)	23.41 (99.27)	22.64 (96.03)
tenderloin	12.56 (100.00)	12.26 (97.66)	11.47 (91.30)	11.49 (91.51)
liver	128.07 (100.00)	125.40 (97.91)	126.02 (98.40)	126.07 (98.44)
heart	95.29 (100.00)	94.58 (99.26)	93.69 (98.33)	93.65 (98.28)

<sup>1</sup> values in parentheses represent heme iron content in frozen sample expressed as percent of that in fresh sample.

<sup>2</sup> frozen at -20 °C and thawed at 20 °C prior to analysis.

TABLE 9. (continue) Heme Iron Contents of Fresh and Frozen Meat<sup>1</sup>

	Heme Iron Content ( $\mu\text{g/g}$ dry weight)			
	Fresh	Frozen <sup>2</sup> 1 week	Frozen 2 weeks	Frozen 4 weeks
<b>Chicken</b>				
leg	13.35 (100.00)	13.44 (100.64)	12.99 (97.27)	12.47 (93.38)
breast	4.43 (100.00)	4.37 (98.67)	4.16 (93.89)	4.06 (91.67)
liver	78.32 (100.00)	76.38 (97.52)	74.88 (95.61)	78.58 (100.33)
heart	74.90 (100.00)	75.45 (100.73)	75.28 (100.50)	74.82 (99.89)
<b>Snake-head fish</b>				
Snake-head fish	3.56 (100.00)	3.72 (104.64)	3.72 (104.39)	3.61 (101.42)
<b>Indo-Pacific mackerel</b>				
Indo-Pacific mackerel	28.21 (100.00)	21.84 (77.42)	22.95 (81.35)	19.84 (70.34)
<b>Green mussel</b>				
Green mussel	252.36 (100.00)	255.56 (101.27)	251.10 (99.50)	252.36 (100.00)
<b>Banana shrimp</b>				
Banana shrimp	2.64 (100.00)	2.49 (94.39)	2.36 (89.67)	2.46 (93.43)

<sup>1</sup> values in parentheses represent heme iron content in frozen sample expressed as percent of that in fresh sample.

<sup>2</sup> frozen at  $-20^{\circ}\text{C}$  and thawed at  $20^{\circ}\text{C}$  prior to analysis.

**TABLE 10.** Nonheme Iron Contents of Fresh and Frozen Meat <sup>1</sup>

=====				
Nonheme Iron Content ( $\mu\text{g/g}$ dry weight)				
	Fresh	Frozen <sup>2</sup> 1 week	Frozen 2 weeks	Frozen 4 weeks
-----				
<b>Beef</b>				
round	63.10 (100.00)	65.14 (103.23)	64.32 (101.92)	65.66 (104.06)
tenderloin	63.84 (100.00)	63.47 (99.42)	64.03 (100.29)	65.86 (103.16)
liver	225.17 (100.00)	229.61 (101.97)	230.90 (102.55)	230.61 (102.24)
heart	113.08 (100.00)	112.82 (99.76)	110.94 (98.10)	113.18 (100.08)
<b>Pork</b>				
round	25.77 (100.00)	24.97 (96.90)	26.21 (101.74)	25.61 (99.39)
tenderloin	20.47 (100.00)	21.91 (107.02)	23.07 (112.67)	20.96 (102.37)
liver	733.81 (100.00)	734.88 (100.15)	740.17 (100.87)	737.84 (100.55)
heart	146.05 (100.00)	149.59 (102.43)	148.84 (101.91)	149.65 (102.47)
-----				

<sup>1</sup> values in parentheses represent nonheme iron content of frozen sample expressed as percent of that of fresh sample.

<sup>2</sup> frozen at  $-20^{\circ}\text{C}$  and thawed at  $20^{\circ}\text{C}$  prior to analysis.



TABLE 10. (continue) Nonheme Iron Contents of Fresh and Frozen Meat<sup>1</sup>

	Nonheme Iron Content ( $\mu\text{g/g}$ dry weight)			
	Fresh	Frozen <sup>2</sup> 1 week	Frozen 2 weeks	Frozen 4 weeks
Chicken				
leg	23.87 (100.00)	22.79 (95.50)	22.47 (94.16)	23.91 (100.17)
breast	41.11 (100.00)	41.30 (100.47)	41.93 (102.00)	41.14 (100.06)
liver	323.10 (100.00)	324.08 (100.30)	326.59 (101.08)	319.54 (98.90)
heart	83.78 (100.00)	81.36 (97.11)	83.04 (99.11)	81.65 (97.45)
Snake-head fish	102.36 (100.00)	103.25 (100.86)	102.03 (99.67)	102.59 (100.22)
Indo-Pacific mackerel	36.61 (100.00)	39.95 (109.11)	42.50 (116.07)	45.51 (124.31)
Green mussel	445.52 (100.00)	436.09 (97.88)	447.06 (100.35)	447.11 (100.36)
Banana shrimp	22.65 (100.00)	23.45 (103.54)	22.56 (99.62)	22.90 (101.10)

<sup>1</sup> values in parentheses represent nonheme iron content of frozen sample expressed as percent of that of fresh sample.

<sup>2</sup> frozen at  $-20^{\circ}\text{C}$  and thawed at  $20^{\circ}\text{C}$  prior to analysis.

After freezing for 1, 2 and 4 weeks, average soluble iron content was increased 14.02%, 19.72% and 35.47% from that of fresh meat, respectively.

Soluble iron level in meat was not significantly changed after frozen for 1 week but the level was significantly increased after 2 and 4 weeks frozen (Table 12). A linear relationship between soluble iron content and the length of freezing time was observed (Figure 13). The regression equation was  $Y = 102.46 + 8.48 X$ , where X was the length of freezing time and Y was the soluble iron content expressed as a percent of that of fresh sample and the corresponding correlation coefficient (r) was 0.9872.

Freezing affected soluble iron contents of different kinds of meat differently. The soluble iron contents of beef round, pork liver, pork heart and chicken liver were increased but in some kinds of meat such as beef tenderloin, beef liver and pork round, soluble iron contents were slightly different from those of fresh samples (Table 11). Furthermore, changes of soluble iron content of red meat, white meat, liver and heart upon freezing were statistically significantly different ( $P < 0.05$ ) among beef, pork and chicken (Appendix C).

TABLE 11. Soluble Iron Contents of Fresh and Frozen Meat<sup>1</sup>

=====				
Soluble Iron Content ( $\mu\text{g/g}$ dry weight)				
	Fresh	Frozen <sup>2</sup> 1 week	Frozen 2 weeks	Frozen 4 weeks
-----				
<b>Beef</b>				
round	7.36 (100.00)	8.88 (120.77)	10.46 (142.20)	11.05 (150.24)
tenderloin	9.21 (100.00)	9.69 (105.19)	11.26 (122.25)	11.74 (127.50)
liver	32.91 (100.00)	30.63 (93.08)	31.30 (95.13)	11.74 (96.91)
heart	9.74 (100.00)	10.19 (104.69)	11.15 (114.52)	12.25 (125.87)
<b>Pork</b>				
round	17.66 (100.00)	17.21 (97.42)	17.68 (100.11)	18.04 (102.12)
tenderloin	9.03 (100.00)	8.13 (89.96)	8.55 (94.59)	9.60 (106.24)
liver	12.33 (100.00)	41.14 (333.67)	51.84 (420.50)	55.70 (451.83)
heart	12.66 (100.00)	14.90 (117.74)	14.53 (114.80)	41.00 (323.95)
-----				

<sup>1</sup> values in parentheses represent soluble iron content of frozen sample expressed as percent of that of fresh sample.

<sup>2</sup> frozen at  $-20^{\circ}\text{C}$  and thawed at  $-20^{\circ}\text{C}$  prior to analysis.

TABLE 11. (continue) Soluble Iron Contents of Fresh and Frozen Meat<sup>1</sup>

	Soluble Iron Content ( $\mu\text{g/g}$ dry weight)			
	Fresh	Frozen <sup>2</sup> 1 week	Frozen 2 weeks	Frozen 4 weeks
Chicken				
leg	4.19 (100.00)	4.85 (115.82)	6.03 (143.96)	6.47 (154.47)
breast	3.03 (100.00)	3.36 (110.73)	4.04 (133.08)	4.52 (148.79)
liver	69.83 (100.00)	71.66 (102.63)	71.92 (102.99)	74.09 (106.10)
heart	8.48 (100.00)	12.81 (151.08)	9.92 (116.95)	11.53 (136.00)
Snake-head fish				
	5.61 (100.00)	5.41 (96.43)	5.26 (93.78)	4.85 (86.54)
Indo-Pacific mackerel				
	13.17 (100.00)	12.17 (92.37)	12.01 (91.15)	12.29 (93.28)
Green mussel				
	28.90 (100.00)	28.67 (99.23)	27.60 (95.52)	28.38 (98.23)
Banana shrimp				
	3.95 (100.00)	4.60 (116.31)	4.88 (123.34)	4.40 (111.21)

<sup>1</sup> values in parentheses represent soluble iron content of frozen sample expressed as percent of that of fresh sample.

<sup>2</sup> frozen at  $-20^{\circ}\text{C}$  and thawed at  $-20^{\circ}\text{C}$  prior to analysis.

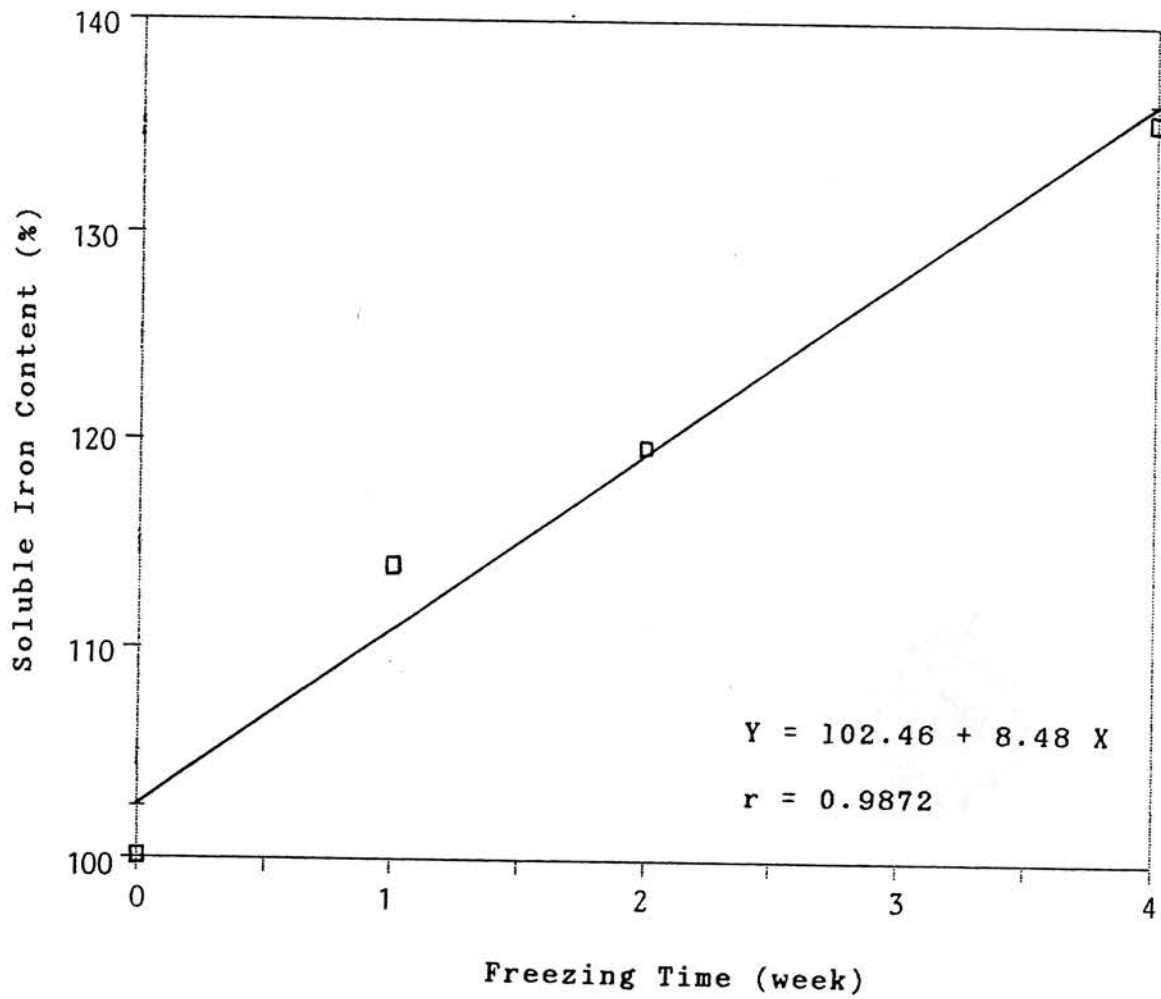


Figure 13. Relationship between Soluble Iron Content of Frozen Meat and the Length of Freezing Time

TABLE 12. Effect of Freezing on Different Iron Contents of Meat<sup>1,2,3</sup>

Iron Content (%)	Fresh	Frozen <sup>4</sup> 1 week	Frozen 2 weeks	Frozen 4 weeks
Heme Iron	79.30 (100.00)	78.30 (98.74)	77.79 (98.10)	77.67 (97.94)
Nonheme Iron <sup>5</sup>	154.27 (100.00)	154.67 (100.26)	156.04 (101.15)	155.86 (101.03)
Soluble Iron <sup>6</sup>	15.62 (100.00)	17.81 (114.02)	18.70* (119.72)	21.16* (135.47)

<sup>1</sup> values represent average iron contents of 16 kinds of meat as listed in Tables 9, 10 and 11.

<sup>2</sup> values in parentheses represent iron content of frozen sample expressed as percent of that of fresh sample.

<sup>3</sup> asterisks indicate statistical difference calculated with reference to raw or fresh sample at  $P < 0.05$ .

<sup>4</sup> frozen at  $-20^{\circ}\text{C}$  and thawed at  $20^{\circ}\text{C}$  prior to analysis.

<sup>5</sup> [nonheme iron] = [total iron] - [heme iron]

<sup>6</sup> [soluble iron] = [total iron in water extract of meat]