CHAPTER IV

DISCUSSION

Iron Contents of Meat

Meat has been considered an excellent nutritional source of dietary iron for man due to its high content of heme iron in myoglobin and hemoglobin (Lawrie, 1979). In this study, the differences of meat iron contents among species as well as among types of tissue were observed. Species difference of iron content of meat agreed with the work of Schricker et al. (1982). Average total and heme iron contents of beef round and beef tenderloin (42.20 and 25.06 µg/g) were higher than those reported by Schricker et al. (1982) who found 26.1 and 16.2 µg/g, respectively. This may be due to the differences in nutritional status, age and sex of animal. However, average total and heme iron contents of pork round and pork tenderloin which were 10.17 and 5.04 µg/g, respectively, were similar to those reported by Schricker et al. (1982).

Generally, muscle which is more exercised tends to be deeper in color and contains higher myoglobin (Charley, 1982). The high level of physical activity of heart in circulating blood by alternate contraction and dilation makes heart muscle require more oxygen, therefore heme iron content of heart muscle is high to accomodate this requirement. This study also found that heme iron content

of heart was higher than that of meat (Table 1). Liver, a body iron storage, contained higher iron than both heart and meat (Tables 1 and 2). In addition, residual blood in liver and heart may also result in the high total and heme iron contents.

In this study, heme iron contents, expressed as percent of total iron, were 59.49%, 48.10% and 20.15% for beef, pork and chicken, respectively. This result was similar to the report of Schricker et al. (1982) who found 62% and 49% for beef and pork, respectively. However, Cook and Monsen (1976 b) reported that heme iron contents ranged from 50-60% of total iron in beef and chicken and 30-40% in pork, liver and fish. The disagreement may be due to the differences in breed, age, sex and nutritional status (Lawrie, 1979).

Myoglobin content of red meat is higher than that of white meat due to its high level of muscular activity. However, a significant difference in heme iron content between red meat and white meat of pig was not found in this study (Table 1). This inconsistency occurred because pork round and pork tenderloin used in this study were not obtained from the same carcass. Even though, chicken leg and breast obtained from the same carcass, were not significantly different in heme iron content (Table 1). These results indicated that there may be other intrinsic factors such as age, sex, breed, nutritional status and level of exercise, besides anatomical location, influenced

upon myoglobin content of animal tissue (Lawrie, 1979).

Not only the protein content of meat, but also the content and form of iron are accounted for nutritive value of meat (Forrest et al., 1975), especially heme and soluble iron which are highly available. In this study, liver and heart contained higher total, heme and soluble iron than did meat; thus, their iron bioavailabilities were expected to be higher than that of meat. Nevertheless, meat is generally consumed much more than liver and heart.

The results of this study showed that beef, pork and chicken were better iron sources than other meat with regard to their higher total and heme iron contents. Beef was the best source due to its highest iron content while pork and chicken which contained the same level of iron lied in the second place (Tables 1 and 2).

Cooked blood contained high total and heme iron contents. Total and heme iron contents were 161.79 and 142.33 μg/g for cooked pork blood and 99.94 and 80.67 μg/g for cooked chicken blood, respectively (Tables 3 and 4). According to high protein and heme iron contents of cooked blood, high bioavailability of iron of the cooked blood was expected. Therefore, cooked or dried blood may be a good iron source for fortification or supplementation in other foods.

Effects of Heat Treatments on Meat Iron Content

This study showed that boiling meat resulted in substantial decrease of heme iron content and consequently increase of nonheme iron content (Table 8). This was a general phenomenon that had been observed earlier in the case of meat pigment extracted by Igene et al. (1979) and Chen et al. (1984). Jansuittivechakul et al. (1985) reported that boiling for 30 minutes caused 13% reduction of heme iron content of lyophilized meat, which was similar to the present study, even though the preparations of sample used in these studies were different. In addition, Schricker and Miller (1983) reported that other household cooking methods such as braising, roasting and microwave cooking increased nonheme iron content of beef round generally less than 10%. Therefore, it appeared that heat treatments using a variety of cooking methods altered heme and nonheme iron contents.

Exposing meat to heat, heme iron content was lower than that of raw sample. This may be due to the change in color of pigment in meat. Upon heating, protein moiety of pigment in meat was denatured, iron was oxidized and the grayish-brown denatured globin hemichrome was resulted. In this study, heme iron content of meat was obtained from the optical density of acid-acetone extract of meat. Therefore, change of pigment color from bright red to grayish brown may cause the lower value of heme iron in heated meat and the higher value of nonheme iron was also

resulted. Nevertheless, Schricker and Miller (1983) reported that much of the additional nonheme iron was apparently derived from heme iron of hemoglobin and myoglobin. They also proposed that heating caused oxidative cleavage of porphyrin ring, thus releasing nonheme iron. This was supported by the results of Chen et al. (1984) which indicated that the increase of nonheme iron was due to the cleavage of iron from porphyrin ring rather than the cleavage of heme, porphyrin with iron, from the globin portion of hemoglobin and myoglobin. However, the exact mechanism of nonheme iron liberation has been questioned.

A gradual decrease of 12%, 19% and 25% in heme iron content of meat was observed after boiling meat for 15, 30 and 60 minutes, respectively. The decreasing in the early period may occurred from the alteration of pigment color but in the late period it may also be the result of the cleavage of porphyrin ring.

A negative relationship between boiling time and the heme iron content of boiled meat and a positive relationship between boiling time and the nonheme iron content of boiled meat were observed in this study (Figures 7 and 8). This observation was similar to that reported by Schricker and Miller (1983) who demonstrated a linear relationship between nonheme iron content of meat and cooking time in a 176 ^{o}C oven. Chen et al. (1984) who worked with meat pigment extract suggested that heating

time or rate of heating instead of temperature was the major factor responsible for the alterations of heme and nonheme iron levels.

It was found in this study that boiling meat for 30 and 60 minutes increased soluble iron content of meat for 54% and 81% (Table 8). Contrary to this finding, Jansuittivechakul et al. (1985) reported that soluble iron content of boiled meat diet was less than that of raw meat diet. Difference between the two studies could be explained mainly on the basis of the fact that, in studies of Jansuittivetchakul et al. (1985), samples were digested with pepsin and pancreatin before determining the soluble iron content by atomic absorption spectrophotometry; whereas, in the present study, samples were blended with water and centrifuged before determining the iron contents by atomic absorption spectrophotometry.

Increasing the boiling time, heme iron content was decreased while soluble iron content was increased. Heme and soluble iron contents of boiled meat were highly correlated ($r = -0.9962$), as depicted in Figure 12. Thus, it was possible that the soluble iron increased upon heating meat may be come from heme iron. This study also found that the increases of soluble iron in boiled red meat and boiled liver were different among beef, pork and chicken while the alterations of heme iron content were not different among these three species. Therefore, it might be other factors associated with the increasing of soluble

iron content, besides the reduction of heme iron content.

Drying is a dehydration method used to preserve meat. Exposure of meat to sunlight is the general drying procedure. In this study, drying at 50-60 ^{o}C for 8 hours was used to simulate heat exposure in sun drying since the method could provide a constant condition for various kinds of meat studied.

After drying at 50-60 ^{o}C for 8 hours, the decrease of heme iron content was 32% while the increases of nonheme and soluble iron contents were 16% and 186%, respectively (Table 8). It was shown that drying caused alterations of iron contents in the same manner as of boiling. However, the decrease of heme iron and the increases of nonheme and soluble iron resulted from drying were significantly ($P<0.05$) greater than those of boiling. This was mainly due to the fact that boiling and drying were different cooking methods. Boiling is a moist-heat method and drying is a dry-heat one. Even though, water was a good heat conductor and its presence aided in the penetration of heat into deeper part of sample, it was found that boiling had less effect on heme, nonheme and soluble iron in meat than did drying. This suggested that other factors such as temperature and the length of heat exposure time may be concerned.

Schricker and Miller (1983) stated that a 10% reduction of heme iron had only a minimal effect on total

absorbable iron in a meal. The severe heat treatments used in this study such as boiling more than 30 minutes and drying at 50-60 °C for 8 hours resulted in an approximately 20-30% reduction of heme iron content (Table 8). Change in heme iron of this magnitude may cause a significant decrease in absorbable iron. Furthermore, decrease in total absorbable iron resulting from heme destruction is greater than that from the increase of nonheme iron (Schricker and Miller, 1983) because heme iron is highly available and its absorption is unaffected by the composition of diet, but availability of nonheme iron is greatly influenced by a variety of enhancing and inhibiting substances present in foodstuffs. Therefore, heat treatment not only decreased heme iron content of meat but also reduced the bioavailability of meat iron. However, this study found that heat treatment also increased the content of soluble iron in meat. The elevated level of soluble iron may increase iron bioavailability of meat because soluble iron was well absorbed. Thus, further *in vivo* study is needed before the effect of heat treatment on bioavailability of meat iron is concluded.

Effect of Freezing on Meat Iron Content

Freezing is a modern method for preservation of meat because microbial growth is inhibited at temperatures below the freezing point of water. In this study, effect of freezing at -20 °C for different storage times on different iron contents of meat was evaluated. The effect

of freezing upon heme iron content had not been widely studied. However, Field et al. (1980) found that freezing at -29 °C for 60 days had no effect on the concentrations of total pigment of muscle and marrow. They suggested that there was no breakdown of pigment occurred during freezing. The present study also found that heme and nonheme iron levels of meat were not affected by freezing although the freezing time was up to 4 weeks (Table 12).

In this study, soluble iron contents of many kinds of frozen meat were slightly different from those of fresh meat (Table 11). It was possible that there were not any alterations resulted from freezing. On the other hand, soluble iron contents of a few kinds of meat were increased after freezing, especially pork liver, of which soluble iron level was elevated from 12.33 to 41.14, 51.84 and 55.70 μg/g after freezing for 1, 2 and 4 weeks, respectively (Table 11). The increasing may be due to the exudation of dripping fluid on thawing because freezing process was associated with mechanical damage of cellular structure resulted from volume enlargement of the contents within cell (Forrest et al., 1975). The damage caused by freezing resulted in a considerble loss of fluid from meat when it was thawed. The leakage of intracellular contents to extracellular pool upon thawing may result in the increase of soluble iron. However, it had been reported that the iron of the frozen foods had a greater solubility than the fresh. Hence, it was possible that freezing may

solubilize the iron in foods (Lee and Clydesdale, 1979 a).

In addition, it was found that alterations of soluble iron content resulted from freezing were different among beef, pork and chicken (Appendix C). The difference was considered as a discrepancy among the contents of iron compounds within the cells which depended on a number of factors such as species, sex and nutritional status as reported in the previous part of this study.

In some kinds of meat that their heme, nonheme and soluble iron contents were not changed upon freezing and thawing, their nutritive values were not affected by freezing. But in some kinds that soluble iron levels were elevated, their iron bioavailabilities may be increased although the heme and nonheme iron contents were not changed. Solubility of iron compound may be a prerequisite of iron absorption and the bioavailability of iron was influenced by the solubility (Lee and Clydesdale, 1979 a; Rizk and Clydesdale, 1983). However, dripping fluid exudated on thawing was frequently discarded prior to cooking, therefore soluble iron, including other water soluble nutrients, was lost (Forrest et al., 1975). Consequently, nutritive value of meat may be reduced after freezing.