The validity of methods used to determine the heme and non-heme iron content in meat products

N. Gibson* & H.C. Schönfeldt
School of Agricultural and Food Sciences, University of Pretoria, South Africa.
*E-mail: nicolette.gibson@up.ac.za.

Introduction

With iron deficiency being the most common nutritional deficiency in the world (Yip in Bowman and Russell, 2001), it comes as no surprise that iron is one of the most investigated micronutrients. Iron deficiency anaemia affects more than 1 billion people, mostly women of childbearing age and young children (Jacobson, 2008). Subsequently many national and international intervention programs have been developed to aid in the elevation of iron deficiency. These include iron fortification and supplementation programs, as well as promotions of the consumption of foods high in iron.

Many foods are naturally high in total iron and many more are fortified with iron, often labelled and marketed as such. However, with varying absorption ratios a singular reference to the total iron content of a food has little value in context of nutrition (Strain and Cashman in Gibney, Vorster and Kok, 2002). The total iron content in a food can be present in two forms, namely either as heme or non-heme iron. The heme form, present in haemoglobin and myogobin of animal products is much more bioavailable than the nonheme iron form, present in the remaining portion of animal products and make up the total iron content of plant foods.

The specific form of iron consumed has a major influence on the absorption of the mineral (Thompson & Manore, 2005). Upon consumption the nonheme portion of total iron enters a common non-heme iron pool in the gastric juice from which the amount absorbed depends on the iron status of the host, as well as other enhancing and inhibiting substances and factors that were consumed prior or with the meal (Strain and Cashman, in Gibney, Vorster & Kok, 2002). In general, the rate of nonheme iron absorption is related to its solubility in the upper part of the small intestine, thus the presence of solubility enhancers and inhibitors consumed during the same meal will have a significant effect on the amount of nonheme iron absorbed (Yip in Bowman and Russell, 2001). Heme iron constitutes a smaller portion of iron present in foods than nonheme iron, and as heme iron is only found in animal sources, it compromises a much smaller proportion of most diets. Although often consumed in smaller amounts, heme iron is 2-3 times more bioavailable than nonheme iron, and is much less affected by other dietary sources (Yip in Bowman and Russell, 2001).

Methodologies used to determine iron bioavailability

In 1978 Monsen et al. reported the first mathematical method to predict iron bioavailability from a given meal. For this method, five parameters are needed. These are the total iron content, heme iron content, nonheme content, ascorbic acid content and the presence of meat, fish or poultry (Monsen et al., 1978). However, various assumptions are included in this calculation, firstly that heme iron absorption is dependent only on body iron stores and not on meal composition, that nonheme iron absorption depends on both body iron stores and the composition of the total meal, and thirdly that all animal tissue contain a heme iron content of 40% and 60% of total iron is considered to be in the nonheme form. According to Wienk, Marx and Beynen (1999) this Monsen method gives a generally good indication of the amount of absorbable iron in a meal, however some factors were not taken into account. The first factor, which is currently under much research, is the lack of incorporating the effect of inhibiting factors present in the meal, which will ultimately affect the amount of nonheme iron absorbed. Secondly no adjustments are made for increase in iron content, although higher iron doses induce a decrease in absolute iron absorption (Wienk et al., 1999). The third factor which questions the validity of using the Monsen method to establish total iron absorption, is that fact that a constant value for heme iron content of all animal products are given as 40%.

The first and second issues have been thoroughly investigated and various models have incorporated and examined the affect of inhibiting and enhancing factors on the absorbability of the nonheme portion (Anand & Seshardi, 1995; Hallberg & Hulthen, 2000; Du, Zhai, Wang & Popkin, 2000; Beard, Murray-Kolb, Haas & Lawrence, 2007a; Beard, Murray-Kolb, Haas & Lawrence, 2007b). Unfortunately, much less has been done to question the validity of using a constant heme iron value in meat foods. Some text books and published articles represent variable heme iron contents in different animal species, for example Strain and Cashman, in Gibney, Vorster and Kok (2002), reports that 30% to 70% of the total iron content in lean meat is in the heme form. However, most nutritional text books, educational tools and methods used to determine the bioavailability of total iron refer to the heme content of all animal derived foods to be 40% of total dietary iron (Wienk et al., 1999; Thompson & Manore, 2002).

Lawrie (1998) commented that beef has a higher iron content than mutton and pork, relating to a higher myoglobin content present in beef. As previously mentioned the heme form of iron is found in the haemoglobin and myoglobin areas, and it can be generally assumed that the heme content in these animal sources higher in myoglobin will also be higher than those lower in myoglobin. This assumption is confirmed by various research findings. According to Neale, in Ledward, Johnston and Knight (1992), the heme iron content in proportion of total iron in meat differs significantly between species. Carpenter and Clark (1995) commented that the heme iron percentages in meat, fish and poultry varies greatly (from 22 up to 80%), and that for red meats the percentage of heme iron is usually more than 40%, while chicken and fish are lower. In Table 1 analyzed heme iron percentages in animal foods are compared.

Table 1. Analyzed heme iron content (%) of total iron in various animal products

Reference	Beef	Pork	Lamb	Chicken
Buchowski, Mahoney, Carpenter & Cornforth (1988)	71	36	ND	ND
Schricker, Miller & Stouffer (1982)	62	36	ND	ND
Hazel (1982)	74	47	59	29
Kalpalathika, Clark & Mahoney (1991)	>60	ND	ND	ND
Clark, Mahoney & Carpenter (1997)	ND	ND	ND	<30

The specific variable amount of heme iron in animal sources plays significant roles in iron absorption as a much greater proportion of heme iron is absorbed compared to nonheme iron, even with the presence of enhancers. In context, a 85g portion of beef steak with 2.7 mg iron, will according to the Monsen model have and a heme content of 1.1 mg (40%), and a nonheme content of 1.6 mg (60%). With the bioavailability of heme iron being 15 to 35%, and nonheme iron being 2 to 20% (Clark et al., 1997), the calculated amount of iron that will be absorbed will be between 0.2 and 0.7 mg, with a high probability of being in the lower range due to higher less bioavailable nonheme iron content. Utilizing an analyzed heme content value of 61.7% (Kalpalathika et al., 1991) in steak, the value of total iron that will be absorbed shifts to between 0.3 and 0.8 mg, with a higher probability to be in the higher range due to higher concentration of more bioavailable heme iron.

Conclusions

As reported by Clark et al. (1997) most literature on the mineral composition of foods only give indication of the total iron content, with no breakdown into the heme or nonheme form. Apart from this lack of fraction information severely affecting the efficacy of predicting bioavailability of the total iron, the utilization of using a simple constant value for heme iron content in animal food sources seem flaccid. And as stated by Beard et al., (2007a) current equations often underestimate iron absorption. It can be concluded that not only is red meats higher in total iron content, but also contain a higher fraction of more readily absorbed heme iron, than the “40%” commonly used.

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