

## **Determining iron bio-availability with a constant heme iron value**

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### **Abstract**

Iron deficiency is the most common and widespread nutritional disorder in the world. Consuming foods rich in dietary iron (high in both content and availability) is an effective way to alleviate iron deficiency. Iron from animal foods is more bio-available than iron from plant sources. This is due to the heme iron content in animal foods. According to the Mosen model, an average of 40% of total iron in meat, fish and poultry is in the heme form. Although the Mosen model can provide a generally good estimate of the heme iron content in animal products, recent research has suggested that the constant 40% value of heme iron is either an under- or over-estimation, depending on the source of the food. During this study a review was performed on the heme iron content of meat, fish and poultry and comparisons are made with reference to the Mosen model.

The aim of this study was to investigate whether using the constant 40% value for heme iron is adequate in describing the bio-availability of total iron in a particular food.

### **Keywords**

Iron; heme iron; bio-availability; iron deficiency; Mosen model, meat, fish, poultry

## **Introduction**

Iron deficiency is the most common and widespread nutritional disorder in the world, affecting approximately 1 billion people globally (WHO/UNICEF/UNU, 2001). The South African National Food Consumption Survey Fortification Baseline (NFCS-FB-1, 2008) reported that 1 out of 5 women and 1 out of 7 children in South Africa have a poor iron status. Data from this survey indicates that iron deficiency is a national public health concern in South Africa, similar to other developing countries. In addition to blood loss, intestinal parasites and insufficient total dietary iron, diet quality (specifically the exclusive consumption of non-heme iron), contributes further to the problem of iron deficiency (Hambræs, 1999). Intervention strategies such as food fortification and supplementation programs have been implemented to help overcome the rising iron deficiency statistics around the world (Schonfeldt, Gibson & Vermeulen, 2010). Although these strategies have been in place for many years, food-based approaches to improve iron status in the general population are more sustainable.

Food-based approaches that help increase iron intake, depends on reliable and relevant data of iron composition (content, as well as availability) of a food. There are two primary forms of iron that are found in food, namely, heme and non-heme (Cook, Dassenko & Lynch, 1991). It is generally accepted that heme iron is more available for absorption than non-heme iron. Heme iron is mainly found in meat, fish and poultry, and according to the Monsen model (1978), makes up about 40% of total iron. Non-heme iron is found mostly in plant-based foods, and makes up the remaining 60% of iron in animal products.

Although non-heme iron constitutes a greater portion of the total iron in foods, its absorption is low and is affected by many factors. The non-heme portion of total iron enters a common non-heme iron pool in the gastric juice once consumed. From this pool, 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 to, or with the meal (Strain and Cashman in Gibney *et al.*, 2002). The bioavailability of non-heme iron is between 2 and 20% (Kalpathalathika *et al.*, 1991; Turhan *et al.*, 2004). In general, the rate of non-heme iron absorption is related to its solubility in the upper part of the small intestine. Thus the presence of soluble enhancers and inhibitors consumed during the same meal will have a significant effect on the amount of non-heme iron absorbed (Carpenter & Mahoney, 1992; Clark *et al.*, 1997; Yip in Bowman & Russell, 2001; Turhan *et al.*, 2004).

Heme iron, although mostly consumed in smaller amounts, is 2 to 3 times more bio-available than non-heme iron and between 15 to 35% is absorbed (Kalpathalathika *et al.*, 1991; Turhan *et al.*, 2004). Heme iron is much less affected by other dietary factors (Carpenter & Mahoney, 1992; Clark *et al.*, 1997; Yip in Bowman & Russell, 2001; Turhan *et al.*, 2004), and contributes significantly to absorbable iron. .

The total iron content of food needs to be further investigated and the heme- and non-heme fractions reported to facilitate development of a sustainable food-based approach to combat iron deficiency.

### **Methods available to determine iron bio-availability**

Literature suggests various models and methods to determine or predict the bio-availability of iron in food. Monsen *et al.* (1978) developed a model to predict total iron absorption. The Monsen model gives a generally good indication of the amount of absorbable iron in a meal. However, some factors not considered include inhibiting factors on non-heme iron absorption and failure to adjust for the enhancing effect of increased iron consumption making a constant adjustment factor of 40% insensitive to the full impact of overall dietary intake on iron absorption.

Inhibiting and enhancing factors have been thoroughly investigated, and taking this into account, various models have incorporated and examined the effects of inhibitors and enhancing factors on the absorbability of the non-heme iron portion (Anand & Seshardi, 1995; Du, *et al.*, 2000; Hallberg & Hulthen, 2000; Beard *et al.*, 2007a; Beard *et al.*, 2007b), the validity of using a constant heme iron value for animal products has not been questioned. Variable heme iron contents in different animal species are reported, for example Strain and Cashman, in Gibney *et al.* (2002), reports that 30% to 70% of the total iron content in lean meat is in the heme form. However, nutritional text books, educational tools and methods used to determine the bio-availability 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).

### **Heme iron content of food**

A review of literature sources of the heme iron content in food furthermore proves that models are developed from highly variable biological data and are not to be considered an absolute,

**Table 1.** The total iron and percentage heme content of cooked beef, pork, chicken and fish as reported by various authors.

Reference	Country	Beef			Pork			Chicken			Fish		
		Sample	Total Fe <sup>a</sup>	% Heme	Sample	Total Fe <sup>a</sup>	% Heme	Sample	Total Fe <sup>a</sup>	% Heme	Sample	Total Fe <sup>a</sup>	% Heme
Purchas et al. (2006)	New Zealand	Longissimus	1.40	75.60									
Turhan et al. (2004)	Turkey	Doners	3.67	46.06				Doners	1.43	34.36			
Kongkachuichai et al. (2002)	Thailand	Loin	2.4	45.00	Loin, tenderloin	1.60	37.95	Breast, drumstick	0.80	22.90	Various	1.75	26.02
Lombardi-Boccai et al. (2002)	Italy	Sirloin, fillet, roast, topside	3.39	77.58	Loin, chump	0.64	60.09	Breast, leg, wing	1.01	27.72			
Hallberg and Hulthen (2000)	Sweden	Rump, sirloin, round, topside, ground, roast	2.55 <sup>b</sup>	46.17	Tenderloin	1.30 <sup>b</sup>	23.00						
Clark et al. (1997)	Utah							Light meat	0.65	26.15			
								Dark meat	1.25	39.20			
Kalpalathika et al. (1991)	Utah	Steak, burger, roast	3.31	58.20									
Average			2.83	58.10		1.12	40.35		1.03	30.07		1.75	26.02

a Total Fe = mg iron/100 g edible portion.

b Expressed as 100 g dry weight.

since the 40% of heme iron in animal food suggested by Monsen *et al.* (1978) is often not consistently found.

Table 1 summarizes different analytically determined heme percentages of various animal foods from different authors. As animal foods are normally consumed cooked, research findings on cooked meats are presented.

**Table 2.** Comparing the Monsen equation to specific analytically derived heme values from different cuts of different species, when predicting the amount of iron (mg) that will be absorbed in the human body<sup>f</sup>.

Species and cut	Total iron (mg/100 g)	Heme iron (mg/100 g)		Non-heme iron (mg/100 g)		Absorbed iron (mg/100 g) <sup>e</sup>	
		Monsen equation <sup>a</sup>	Literature value <sup>b</sup>	Monsen equation <sup>c</sup>	Literature value <sup>d</sup>	Monsen equation	Literature value
Beef, steak (Kalpalathika et al., 1991)	3.42	1.37	2.12	2.05	1.30	0.38	0.53
Chicken, light meat (Clark et al., 1997)	0.65	0.26	0.17	0.39	0.48	0.07	0.05
Pork, loin (Kongkachuichai et al., 2002)	2.4	0.96	1.1	1.44	1.3	0.26	0.29
Fish, catfish (Kongkachuichai et al., 2002)	1.8	0.72	0.50	1.08	1.30	0.20	0.15

a Calculated as 60% of total Fe (Monsen et al., 1978).

b Calculated by multiplying analytically derived heme iron content (%) with total iron.

c Calculated as 40% of total Fe (Monsen et al., 1978).

d Calculated by multiplying analytically derived non-heme iron content (%) with total iron.

e Bio-availability of heme iron calculated as 23%, and non-heme iron as 3% ([Monsen et al., 1978] and [Du et al., 2000]).

f No adjustments were made for enhancers/inhibitors.

### **Inconsistent total iron bio-availability values**

In Table 2, the data of constant heme and non-heme iron fractions as used by Monsen *et al.*, is (1978) compared with analytically derived values. A 100 g portion of beef steak with 3.42 mg iron, will, according to the Monsen model, have a heme content of 1.37 mg (40%), and a non-heme content of 2.05 mg (60%). The calculated amount of total iron absorbed based on the bio-availability of heme iron calculated as 23%, and non-heme iron as 3% (Monsen *et al.*, 1978; Du *et al.*, 2000) will be 0.38 mg. Using the analyzed heme content values reported in the literature, of 61.75% in beef steak (Kalpalathika *et al.*, 1991), the calculated value of total iron absorbed increases to 0.53 mg. In contrast, 100 g light meat chicken containing 0.65 mg iron, will according to the Monsen model result in 0.07 mg being absorbed, while the analyzed heme content values ( Clark *et al.*, 1997) indicate an actual lower absorption of 0.05 mg iron. Table 2 shows the biological variability in analytical values, as compared to a constant value (40 %) used in the Monsen model.

### **Conclusion**

In the context of combating iron deficiency, a multiprong approach of fortification, supplementation and food-based strategies are advised. However, food-based strategies implemented to overcome iron deficiency require relevant and current scientific evidence to maximise efficacy. With animal products as a significant dietary source of iron, using a constant heme and non-heme value to calculate the iron bio-availability of meat products can over- or under-estimate the actual bio-availability of total iron. It is clear that with the great number of iron deficiency statistics, either insufficient iron is provided by the diet or the diet comprises mostly of non-heme iron. Determining the bio-availability of total iron, through accurate data

regarding heme content will support the long-term food-based strategy in overcoming iron deficiency. Clark *et al.* (1997) reported that most literature on the composition of foods only give an indication of the total iron content, with no breakdown into the heme or non-heme fractions. Apart from the lack of fraction information affecting the efficacy of predicting total iron bio-availability, the utilizing of a constant value for heme iron content in animal products would be effective in public health situations, but more precise data may be needed to guide specific nutritional planning. . Taking this into account, further research on heme content of animal products is required to enable accurate determination of total iron bio-availability.

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