NUTRITIONAL CONTRIBUTION OF RED MEAT IN THE DIET – THE STATE OF ART

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Introduction

The International Meat Secretariat (IMS) Human Nutrition and Health (HNH) Committee was formally established in 2004. Its membership includes a number of meat industry nutritionists from around the world. At the time it was agreed that certain synergies could be gained by working together, as individual industry organisations had limited expertise in this field, typically employing only one nutritionist in each country. Many countries have no formal organisation supporting their meat industry. The Committee's terms of reference are to advise the IMS on matters relating to human health and nutrition, to promote nutrition within the IMS and to act as a specialist group in contact with international organisations dealing with health and nutrition.

The HNH Committee recognised that if the meat industry was to effectively defend itself against ongoing negative criticism, it would need to amass a sound scientific evidence base. Thus, the Committee has established a regular dialogue, sharing the results of research and in some cases funding research where gaps exist. All this activity is based on the guiding principle that advice given is based on existing scientific evidence and appropriate dietary recommendation. The promotion of red meat globally is done within this context and in the context of a healthy balanced diet and lifestyle. However, it was identified at the time that there were gaps in the evidence base, and that the main health benefits associated with eating red meat relating to its nutritional composition, were being frequently overlooked in the literature.

In December 2004, the British Nutrition Foundation (BNF) was commissioned by the Meat and Livestock Commission (MLC) on behalf of the IMS HNH Committee to prepare a scientific review of red meat in the diet.

BNF is a scientific and educational charity, which promotes the well being of society through the impartial interpretation, and effective dissemination of evidence based nutritional knowledge and advice. It works in partnership with academic and research institutes, the food industry, educators and government. Its members include many of the UK's leading food industry companies.

The BNF was given a broad brief. The review should examine red meat consumption patterns, dietary and lifestyle factors associated with meat consumption and the effects of red meat intake on health and chronic disease outcomes. Both negative and positive aspects needed to be considered in order to present a balanced view which would withstand peer review. Individual organisations were able to contribute country specific data.

This resulted in a comprehensive review report which has now been published (BNF 2005). The purpose of this paper is to give a summary of the key findings. It will focus on the health aspects of red meat in relation to links with chronic disease (particularly colorectal cancer (CRC) and cardiovascular disease (CVD)). Issues such as the definition of red and processed meat, consumption, composition, contribution to the diet and dietary and lifestyle aspects of red meat consumers are discussed. The intention is to present a condensed version of the review to a wider meat science and meat industry audience who may have otherwise been unaware that this work has been done.

Defining Red and Processed Meat

Much of the evidence investigating associations between meat intake and health/disease outcomes is based on epidemiological studies. Not all studies define what is meant by meat and, where definitions are offered, they are not always the same, which can make comparisons between studies difficult. Some studies include poultry under the definition of meat, while others exclude it; some look at total meat consumption (including red meat and processed meat), while others analyse red meat and processed meat separately. In general, red meat refers to beef, pork and lamb in main dishes and processed meat refers to meat products, such as sausages, burgers and smoked, cured and tinned meats. Offal is also a form of meat, but there is little epidemiological evidence specific to this category of meat.

The following definitions for red and processed meat are based on definitions currently used in epidemiological studies looking at the health effects of meat consumption, such as the European Prospective Investigation into Cancer and Nutrition (EPIC) study.

Red meat includes beef, veal, pork and lamb (fresh, minced and frozen).
Processed meat includes meat that has been preserved by methods other than freezing, such as salting, smoking, marinating, air drying or heating *e.g.* ham, bacon, sausages, hamburgers, salami, corned beef and tinned meat.

Red Meat Consumption

Data from national dietary surveys indicate that intakes of meat vary widely between countries, and between subgroups of the population within countries. However, some similarities have been found; for example, women tend to consume less meat than men. As different methodologies are adopted to collect information on food intake, it is difficult to make direct comparisons between data from different countries. Table 1 shows average daily intakes of red and processed meat in a range of European countries, as determined by the EPIC calibration study.

Table 1: Mean daily intake (g/day) of total meat, red meat, processed meat and red + processed meat in selected countries participating in the EPIC calibration study.

	Total meat*		**Red meat**		**Processed meat**		**Red meat + processed meat**	
	Men	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**	**Women**
Greece	78.8	47.1	45.3	25.5	10.0	5.8	55.3	31.3
Spain	170.4	99.2	74.0	37.8	52.8	29.6	126.8	67.4
Italy	140.1	86.1	57.8	40.8	33.5	19.6	91.3	60.4
Germany	154.6	84.3	52.2	28.6	83.2	40.9	135.4	69.5
Netherlands	155.6	92.7	63.8	41.0	72.4	37.9	136.2	78.9
UK	108.1	72.3	40.0	24.6	38.4	22.3	78.4	46.9
Denmark	141.1	88.3	69.6	44.1	51.9	25.3	121.5	69.4

*Total meat includes pork, beef, veal, lamb/mutton, poultry, game, rabbit, horse, goat and offal.
Source: Linseisen *et al.* (2002)

When considering the health effects of red meat consumption, it is useful to consider how meat is consumed as part of the diet (*e.g.* portion size) and the type of meat consumed. From the EPIC data it is evident that different European countries favour certain meats.

Data from the recent North/South Food Consumption Survey for Ireland found that, compared to all meats, portions of beef and veal were largest (on average 60g), and consumed by 55% of the sample (Irish Universities Nutrition Alliance, 2001). According to the survey, the most commonly consumed meats in Ireland were bacon, ham and processed meats (consumed by 71% of the sample). Average meat intake increased from 87g to 134g per day when intakes of all processed and carcass meats were included, although the average intake of processed meat was lower than for red meat alone.

In the UK, bacon and ham were also the most commonly consumed meats (77% men and 64% of women consuming these products) (Henderson *et al.* 2003a). Overall, carcass meat consumption in the UK has been recorded at just 32g per day (Department of Food and Rural Affairs, 2005). However, this does not take into account ready meals and convenience meat products that have become very popular in the UK. The popularity of these foods, along with other meat products such as meat pies, makes it difficult to accurately measure the average amount of red meat consumed. For example, data from the North/South Ireland Food Consumption Survey found that there was a 43% overestimation of meat intake, without disaggregation of composite foods (such as lasagne, sausage rolls) (Cosgrove, 2005a).

Nutrient Composition

Another challenging aspect of investigating patterns of red meat intake is that the composition of different types of meat varies widely. For example, lean red meat is low in total fat, saturated fatty acids (SFAs) and salt, whereas untrimmed meat is higher in both total fat and SFAs; processed meat is generally higher in salt and fat and often contains other components, such as nitrites, which are added during processing. Moreover, the composition of different processed meats and the types of processed meat consumed vary widely between countries. It is therefore important to distinguish between different types of meat when looking at patterns of intake, as well as considering the health effects of red meat. This is not always straightforward, however, as definitions vary and not all studies distinguish between different kinds of meat consumed.

Data on the nutrient composition of red meat are available in food composition tables and databases. There are over 150 food composition tables and electronic databases worldwide and undoubtedly meat and meat products will be listed in all of these, although slightly different nutrient values are likely to be found in different versions. Table 2 shows the nutrient composition of 100g of lean raw beef, lamb and pork according to the food composition tables of four different countries, and illustrates how these figures can vary.

Meat is principally composed of protein (which provides 17kJ/4kcal of energy per gram), but also contains fat in varying amounts (providing 37kJ/9kcal of energy per gram). The more fat that meat contains, the higher the energy content will be, as shown in Table 3.

Table 2: Comparison of selected nutrients in beef, lamb and pork (per 100g) according to food composition databases from four countries.

	Denmark	UK	Australia	USA
Beef, lean, raw				
Energy (kJ)	470	571	520	531
Protein (g)	22.3	22.5	23.0	22.3
Fat (g)	2.5	5.1	3.6	3.5
Niacin (mg)	10.1	5.0	3.0	6.5
Vitamin B_{12} (µg)	1.4	2.0	1.1	0.9
Iron (mg)	2.4	1.8	2.0	1.6
Zinc (mg)	4.7	4.1	4.2	4.0
Selenium (µg)	6.5	7.0	10	30.8
Lamb (leg), lean, raw				
Energy (kJ)	545	651	501	561
Protein (g)	20.2	20.2	20.4	20.5
Fat (g)	5.5	8.3	4.2	5.1
Niacin (mg)	7.5	5.4	5.6	6.3
Vitamin B12 (µg)	1.2	2.0	0.9	2.8
Iron (mg)	2.2	1.4	2.3	1.8
Zinc (mg)	3.3	3.3	3.4	3.8
Selenium (µg)	1.4	2.0	10.0	23.4
Pork, lean, raw				
Energy (kJ)	445	519	N/A	502
Protein (g)	21.6	21.8	N/A	20.9
Fat (g)	2.1	4.0	N/A	3.4
Niacin (mg)	7.3	6.9	N/A	4.4
Thiamin (mg)	0.8	1.0	N/A	1.0
Vitamin B_{12} (µg)	0.7	1.0	N/A	0.8
Iron (mg)	0.7	0.7	N/A	1.2
Zinc (mg)	3.6	2.1	N/A	2.0
Selenium (µg)	6.9	13.0	N/A	28.9

N/A: data was not available.

Sources: Danish Institute for Food and Veterinary Research (2005b); Chan *et al.* (1995); Red Meat and Health Expert Advisory Committee (2001); United States Department of Agriculture (2005).

Table 3: Energy, fat and protein content of lean and untrimmed cuts of red meat (per 100g; UK figures).

Meat (barbequed or grilled)	Energy kJ (kcal)	Fat (g)	Protein (g)
Rump steak – lean	741 (176)	5.7	31.2
Rump steak - lean and fat	849 (203)	9.4	29.5
Leg joint of lamb – lean	879 (210)	9.6	30.8
Leg joint of lamb – lean and fat	986 (236)	13.0	29.7
Loin chops of pork – lean	780 (186)	6.8	31.1
Loin chops of pork – lean and fat	1066 (255)	15.8	28.3

Source: Chan *et al.* (1995).

Advances in food processing technologies and breeding programmes, as well as modification of animal feeds and modern butchery techniques have all led to a reduction in the fat content of carcass meat over the past 15 years. For example, the fat content of carcass meat in the UK has been reduced by over 30% for pork, 15% for beef and 10% for lamb (Higgs, 2000; Lee *et al.* 1995). New Zealand has seen similar changes, and in particular has worked with butchers to encourage the trimming of fat from red meat before sale, through the introduction of a 'Quality Mark'. These efforts have resulted in a 48% reduction of fat in beef, and a 43% reduction in lamb (Laugesen, 2005).
Overall, lean red meat contains similar proportions of monounsaturated fatty acids (MUFAs) to saturated fatty acids (SFAs), although as illustrated in Table 4, the exact proportions vary depending on the type of meat (Chan *et al.* 1995).

Table 4: Typical fatty acid composition (g/100g) of different types of red meat (lean only, cooked) (UK figures).

	Beef	**Lamb**	**Pork**	**Bacon (grilled)**
Total SFA	3.26	5.36	2.31	7.91
Total MUFA	3.41	4.06	2.56	8.85
Total PUFA	0.38	0.59	1.15	2.71
n-6 PUFA	0.36	0.48	1.02	2.41
n-3 PUFA	0.09	0.23	0.12	0.31

Source: MAFF (1998).

Although red meat is seen as a contributor to SFAs intake, lean red meat actually contains a higher proportion of unsaturated fatty acids (see Table 4). Meat, primarily lean meat, also contains the long-chain *n*-3 fatty acids, eicosapentaenoic acid (EPA) and docosapentaenoic acid (DPA). Although levels of these are low, there are few other food sources (the richest source being oily fish), and therefore lean red meat can make a contribution to intake of these fatty acids. Indeed, an Australian study has shown that beef, lamb and pork provide 32% of these fatty acids to the diet (Howe *et al.*, 2003). Furthermore, much work is currently underway to identify methods through which to alter the fatty acid profile of foods, such as meat, in order to reflect a positive fatty acid profile in terms of heart health (Givens and Shingfield 2004).

Meat from ruminant animals is a source of another *naturally occurring* fatty acid - conjugated linoleic acid (CLA). CLA is a collective term used to describe a mixture of positional and geometric isomers of linoleic acid. CLA is found naturally in small amounts in products from ruminant animals *e.g.* lamb, beef, cheese and milk. Feeding practices influence the CLA content of meat. For example, concentrations of CLA in Irish and Australian beef can be 2 to 3 times higher than those in beef from the USA, reflecting the greater consumption of pasture throughout the year (Moloney, 2006). Based largely on animal studies in rodents, there is interest in the potential health benefits of CLA in humans in connection with cancer, blood lipids and an influence on the lean:fat tissue ratio (in favour of lean tissue) (Calder, 2002); however, no clear conclusions have yet been made with respect to human health.

Processed meats and meat products that contain lower amounts of lean meat are likely to have a lower micronutrient content per 100g, but may provide other nutrients not usually found in meat (*e.g.* carbohydrate and fibre). Also, the addition of some ingredients (*e.g.* soy, fibre) can be used to add functional properties to meat products that could offer potential benefits for health (Fernandez-Gines *et al.*, 2005).

Overall meat products and processed meats are more likely to have a higher content of sodium than lean meat. Sodium is added to meat products to enhance and modify the flavour, the physical properties and sensory attributes of the food, and to contribute to the preservation of the product (Matthews and Strong 2005). Owing to the adverse health effects associated with a high intake of sodium, work is underway within the UK to reduce the amount of salt in processed meat products and, in particular, products that contain the highest levels of sodium (Matthews and Strong 2005).

Contribution to Nutrient Intake

Despite the variations in composition with country, species, cut, fatty acid profile and in some cases the reformulation of processed meat products, meat and meat products can make an important contribution to nutrient intakes in the diet. They provide a number of essential nutrients, including protein, long-chain *n*-3 fatty acids, iron, zinc, selenium, vitamin D and vitamin B_{12}.

Red meat is a well recognised source of bioavailable iron, contributing around 20% of iron intake, on average, in developed countries (Henderson *et al.*, 2003b; Russell *et al.*, 1999). In the light of current low levels of iron intake in many developed countries, particularly among women, meat has the potential to make an important contribution to intakes. A number of studies have confirmed the positive effect of including meat in the diet, on intakes of iron. For example, a study by Gibson and Ashwell (2003) found an increased risk of low iron intake (below the UK LRNI) in those who ate the least meat and processed meat ($\leq$90g per day), compared with high consumers ($\geq$140g per day).

In some countries, for example the UK, there are also concerns over low intakes of selenium (BNF2001;SACN 2005b). Meat is one of the main providers of selenium in the diet, particularly in parts of the world where selenium levels in the cereals consumed are low.

Red meat is also classified as a *source* of zinc, in EU food labelling terms (BNF 2002). Red meat consumption provides 30-40% of the recommended zinc intake in some countries. As with iron, the zinc in meat is in a highly bioavailable form, making meat a more 'efficient' provider of this mineral. Concern exists, *e.g.* in the UK, about the zinc intakes of some population groups (Henderson *et al.*, 2003b).

Red meat also contains a range of B vitamins, although the levels vary between types of meat, in particular it is classified as a *rich source* of vitamin B_{12}, in EU food labelling terms. As this vitamin is only found naturally in foods of animal origin, sub-groups of the population who do not consume meat or animal products may have inadequate intakes (Herbert, 1988;1994).

Red meat is also a good source of vitamin D, which may be more easily utilised than the vitamin D present in other foodstuffs (Groff *et al.*, 1995). Furthermore, it has been suggested that components of meat protein may enhance the utilisation of vitamin D in humans, particularly where exposure to sunshine is limited (Dunnigan and Henderson 1997).

Diet and Lifestyle Factors Associated with Red Meat Consumption

There are relatively few large-scale studies that have looked at the dietary and lifestyle habits of meat-eaters compared to other dietary groups, such as vegetarians. However, this topic has recently been examined in two large UK cohorts: the EPIC-Oxford cohort (Davey *et al.*, 2003) and the UK Women's Cohort Study (Cade *et al.* 2004). Some distinct differences in the diet and lifestyle characteristics of meat-eaters, compared to other dietary groups have been highlighted. In particular, meat-eaters seem to be generally older, have a higher BMI (which may be linked) and are more likely to smoke compared to non meat-eaters. As might be expected, nutrient intakes were found to differ between meat-eaters and other dietary groups. Meat-eaters were found to have higher protein, total fat and SFA intakes and lower carbohydrate and fibre intakes than non meat-eaters, and their consumption of fruit and vegetables was also lower. Marked differences in micronutrient intakes were also found.

However, it is noteworthy that these cohort studies do not differentiate between consumers of unprocessed and processed meat. A recent cross-sectional study of Irish adults indicates that it is important to distinguish between meat groups as there is a large variation in dietary quality between consumers of red meat, white meat and processed meat. For example, increasing processed meat intake has been found to be associated with a lower intake of wholemeal bread, fruit and vegetable and fish intake and poorer overall dietary quality (Cosgrove *et al.* 2005b).

The variation in diet and lifestyle characteristics between meat-eaters and non meat-eaters may have important implications for associations between meat consumption and health and disease. However, vegetarians represent only a small minority of the population *e.g.* in the UK it is estimated that around 3-7% of the population are vegetarian (Phillips 2005). Furthermore, the mortality rates of vegetarians are similar to those of comparable non-vegetarians, suggesting that much of this benefit may be attributed to non-dietary factors, such as lower prevalence of smoking or to other aspects of the diet other than the avoidance of meat and fish *e.g.* higher intake of fruit and vegetables (Appleby *et al.*, 2002).

Health Aspects of Red Meat

Various research studies have been conducted to try to determine whether there is a link between red and processed meat intake and a number of conditions, including colorectal cancer (CRC), cardiovascular disease (CVD), obesity and type 2 diabetes.

Colorectal cancer (CRC)

Most of the published literature on meat in relation to cancer development has focused on CRC. There have been some studies investigating possible associations between meat and other types of cancer, including gastric, breast, prostate and kidney cancers and cancer of the pancreas, however the evidence in relation to these other types of cancer has been found to be weak or inconsistent (Department of Health, UK, 1998; Key *et al.*, 2004).

The scientific interest in the association between red and processed meat intake and CRC over recent years has generated a number of reviews, including two large reports, one from the World Cancer Research Fund (WCRF) and another from the UK Committee on Medical Aspects of Food and Nutrition Policy (COMA). Both panels agreed that the results of epidemiological studies were not consistent. The conclusion of the WCRF (1997) report was that "The evidence shows that red meat *probably* increases risk and processed meat *possibly* increases risk of colorectal cancer". A new analysis from the WCRF is expected in 2007.

The COMA report (Department of Health, UK, 1998) concluded that "there is moderately consistent evidence from cohort studies of a positive association between the consumption of red or processed meat and risk of colorectal cancer." This report recommended that the current, average level of red and processed meat intake in the UK should not increase. Those with high levels of intake (>140g per day) were recommended to reduce their consumption.

CRC is the third most common cancer in the world. In 2002, CRC was estimated to account for over a million new cancer cases worldwide (9.4% of all cancer cases) (Ferlay *et al.* 2004). Genetic changes associated with colorectal cancer are well established and inherited mutations in key genes are considered to be responsible for about 20% of cases. The remaining 80% of cases are sporadic (*i.e.* arise spontaneously) and appear to be influenced by environmental and lifestyle factors, such as diet and physical activity level. This is also supported by the findings of epidemiological studies (see below).

Incidence rates for CRC are approximately 10-fold higher in developed compared to developing countries (Ferlay *et al.*, 2004). Changes in incidence rates have also been noted in populations over time. CRC was very rare in Japan in the 1960s, however there has been an almost five-fold increase in CRC in Japanese men over the past 30 years, and incidence in Japanese men aged 55-60 is now twice that of men in the UK. This cannot all be attributable to genetic effects as there cannot have been such a rapid change in the Japanese gene pool over such a short period of time. Environmental factors such as diet, therefore, must play a part (Bingham and Riboli, 2004).

It has been suggested that the contribution of diet to CRC incidence could be as much as 80% (Willett, 1995). If this is the case, it means that the majority of CRC cases may be preventable. Few specific diet-related factors have been shown unequivocally to contribute to the pathogenesis of CRC, however, there is a general consensus that some aspects of the western diet increase the risk of CRC, owing to the large variation in incidence between developed and developing countries (World Health Organisation, 2003).

Table 5 shows diet-related risk factors for which there is evidence of an association with CRC risk. Also, it has been shown that risk factors tend to cluster, so individuals who are obese will often be physically inactive, smoke and consume low levels of fruit and vegetables and high levels of meat (Potter, 1999).

Table 5: Diet-related risk factors for CRC (from Key *et al.*, 2004).

Diet-related risk factor	Level of evidence
Overweight/obesity	Increases risk (best established diet-related risk factor)
Physical activity	Consistent association with reduced risk
Fruit and vegetables	*Probably* decreases the risk
Red and processed meat	*Probably* increases risk
Alcohol	*Probably* contributes to a small increase in risk

There is some evidence that several other diet-related factors may be associated with a reduced risk of CRC, including dietary fibre, folate, calcium and vitamin D. Evidence in relation to folate, calcium and vitamin D intake has not been firmly established, however, recent findings from EPIC study have shown dietary fibre to be inversely related to CRC incidence (Bingham *et al.* 2003).

In the UK, the incidence of CRC has increased substantially over the past 35 years, yet red meat intake has declined by around 25% over the same period. A similar pattern has been seen in other European countries, such as Norway, where risk of CRC has increased by 50% over the same period (Hill, 2002).

Table 6 shows the mean daily intake of different types of meat for 10 European countries from the EPIC study (females only shown) together with CRC incidence for each country. Meat consumption in the UK was found to be less than in many Mediterranean countries, such as Spain and Italy, and yet CRC incidence is higher in the UK than several Southern European countries.

The two meta-analyses carried out by Sandhu *et al.* (2001) and Norat *et al.* (2002) provide evidence from the combined results of cohort (and case-control) studies of an association between high red and processed meat intake and CRC risk. This is supported by the results of some more recent large prospective studies, such as the EPIC cohort. EPIC results also indicate that processed meat intake may be a stronger risk factor for CRC than red meat intake (Norat *et al.* 2005).

The underlying mechanism for this association is still uncertain, although recent human intervention studies have suggested that the endogenous *N*-nitrosation arising from ingestion of haem iron (not inorganic iron or protein) could be the most likely mechanism (Cross *et al.* 2003). This would also help explain why poultry, which contains much lower amounts of haem, is not associated with increased CRC risk. It has been suggested that processed meat intake is more strongly associated with CRC risk than unprocessed red meat, however, there is currently no straightforward mechanism that could explain this. Nitrites or nitrates added to meat during processing could increase exogenous exposure to nitrosamines and other NOCs, but not all processed meats contain added nitrites (Norat *et al.* 2005).

Table 6: Variation in meat consumption and CRC incidence across 10 EPIC countries.

	Mean daily intake (g/day)					
	All meat	Red meat	Poultry	Sausages	Other processed	CRC Incidence (ASR)
Denmark	88.3	44.1	16.8	15.6	9.8	19.2
Norway	88.6	28.5	10.6	22.9	23.6	16.8
Germany	84.3	28.6	13.0	29.4	11.5	15.7
The Netherlands	92.7	41.0	12.4	16.4	21.5	14.4
UK	72.3	24.6	24.0	9.3	13.0	12.4
France	106.0	44.4	21.8	12.2	17.8	11.8
Spain	99.2	37.8	24.4	13.1	16.5	11.3
Sweden	92.3	32.3	9.3	21.3	22.0	11.1
Italy	86.1	40.8	20.2	9.52	10.1	10.9
Greece	47.1	25.5	11.8	3.1	2.8	8.0

Data shown taken from EPIC calibration study (females only). Data adjusted for age, day of the week, season (Linseisen *et al.* 2002). CRC incidence reported as age standardised (world) rate (ASR) per 100,000 (Ferlay *et al.* 2004)

It is important to put these findings in context, however. Red and processed meat intake is only one of a number of potential risk factors for CRC. Indeed, the most established diet-related risk factors for CRC are overweight and obesity and low physical activity level. Therefore reducing the risk of CRC involves modification of a number of dietary and lifestyle factors including maintaining a healthy body weight, increasing physical activity level and consuming more fruit and vegetables and dietary fibre (Slattery, 2000).

Moreover, whether the consumption of meat is an *independent* risk factor for CRC is still not certain. Colorectal carcinogenesis is a multi-step process involving many different factors; a number of biological pathways may be involved and an accumulation of alterations to DNA occur. It is therefore unlikely that factors determining CRC risk act in isolation. Furthermore, because not all studies have actually examined the independent effect of meat intake, it is not possible to exclude the possibility that the association may be confounded by other dietary, genetic or associated factors (Sandhu *et al.* 2001). Further studies with long-term follow-up, repeated measures of diet, more in depth consideration of dietary patterns, more detailed measures of cooking methods, and genetic markers of susceptibility may therefore be required (Willett, 2005).

Nevertheless, a picture seems to be emerging that patterns of food intake are important, *i.e.* any increased risk associated with a high intake of red and processed meat appears to be lessened if dietary fibre intakes are increased (Norat *et al.* 2005). Thus lean red meat is unlikely to significantly increase the risk of CRC when consumed in moderation and as part of a healthy balanced diet that includes plenty of fibre from fruit, vegetables, pulses and whole grain cereals.

Thus, currently available evidence suggests that the UK guidelines set by COMA with respect to reducing CRC risk are still appropriate. These suggest that an individual's consumption of red and processed meat should not rise and that higher consumers (> 140g per day or 12-14 portions per week) should consider a reduction in intake (Department of Health, UK, 1998). It is worth noting that recommendations in different countries vary somewhat; for example, the Australian Cancer Council of New South Wales (NSW) recommends that people consume moderate amounts of red meat (65-100g of cooked red meat, 3-4 times a week) and limit consumption of processed meats (The Cancer Council NSW, 2003). The American Cancer Society recommends limiting consumption of red meats, especially those high in fat and processed meat (American Cancer Society, 2001).

Average daily intakes of red and processed meat in most countries are still below the level thought to increase the risk of CRC. For example, average intakes of red meat in Europe (in men) range from 40g per day in the UK to 74g per day in Spain, while average intakes of processed meat (in men) range from 10g per day in Greece to 83.2g per day in Germany (see Table 1) and therefore it is only the small proportion of high consumers of meat and meat products that may need to consider a reduction in consumption.

Cardiovascular Disease (CVD)

CVD, which includes coronary heart disease (CHD) and stroke, is the leading cause of death worldwide, accounting for 18 million deaths each year. It has a multifactorial aetiology. Although there are a number of unmodifiable risk factors, including a genetic predisposition, many of the major causes such as hypertension, obesity, diabetes, high blood cholesterol and high blood triglyceride concentrations are modifiable by diet, along with other lifestyle factors (*e.g.* physical activity and smoking cessation) (Stanner 2005).

Meat has often been assumed to be a contributor to increased risk of heart disease because of its relatively high contribution to fat intakes and its perceived high content of SFAs, but as previously discussed advances in food processing technologies and breeding programmes, as well as modification of animal feeds and modern butchery techniques have all led to a reduction in the fat content of carcass meat over the past 15 years.

Prospective studies have demonstrated a positive association between meat and CVD risk, but any causal link remains to be established. For example, Fraser (1999) reported a significant association between beef consumption and fatal CHD in a male cohort of Seventh-Day Adventists, with those eating beef up to 3 times a week having a 1.9-fold increased risk, and those eating beef 3 or more times a week having a 2.3-fold increased risk, compared to vegetarians. However, the study found no association in women and no significant increase in risk of non-fatal myocardial infarction (MI). Subdivision of subjects in a pooled analysis of vegetarian studies into meat-eaters (those eating meat more than once a week), occasional meat-eaters (less than once a week), fish-eaters and vegetarians, demonstrated the death rate ratio to be significantly below 1 for occasional meat-eaters, fish-eaters and vegetarians, using the meat-eaters as the reference population (Key *et al.* 1998; 1999a).

In the Nurses' Health Study, consumption of red meat was associated with an increased risk of CHD, after adjustment for age (relative risk for one additional serving per day was 1.43, 95% CI:1.35-1.65) and this was attributed to its contribution to intake of SFAs (Hu *et al.* 1999a). However, the association was substantially attenuated and no longer significant in multivariate analyses.

In the Iowa Women's Health Study, higher consumption of red meat was significantly associated with CHD mortality (risk ratio 1.44, 95% CI: 1.06 - 1.94) (Kelemen *et al.* 2005). Amongst a cohort of men in the US, intake of haem iron, particularly from red meat, was significantly related to increased risk of fatal CHD or non-fatal myocardial infarction (MI) after adjustment for dietary cholesterol and fats (Ascherio *et al.* 1994). As meat- eaters vary from non or infrequent meat eaters in a number of ways (*e.g.* they are often more likely to smoke and have a higher BMI), it is very difficult for studies to isolate the effects of meat *per se,* even if they correct for a number of recognised potential confounders. Moreover, none of these investigations have attempted to distinguish between the effects of different types of meat, particularly lean versus untrimmed meat or processed versus unprocessed meat.

Dietary intervention studies have, however, suggested that whilst untrimmed meat is cholesterol-raising, this is not true of diets containing fat-trimmed lean meat. Most studies have demonstrated lean red meat to have similar effects on total, LDL- and HDL-cholesterol or triglyceride levels as white meat or soybean products (Li *et al.* 2005). In fact, a recent review of dietary intervention and cross-sectional studies concluded that diets low in SFAs and containing lean red meat are associated with a reduction in LDL-cholesterol levels in both healthy subjects and those with hypercholesterolaemia. Studies also suggest that lean meat does not have an adverse effect on blood lipids in patients with existing CVD (Watts *et al.* 1988). Lean red meat was also found to have no effect on thrombotic risk factors (Li *et al.* 2005).

Meat from ruminant animals contains some *trans* fatty acids as well as conjugated linoleic acid (CLA). *Trans* fatty acids are recognised to have a more potent effect on blood cholesterol than SFAs, by raising levels of LDL-cholesterol and lipoprotein (a) and decreasing HDL-cholesterol levels, although this may not occur with the natural *trans* fats in meat and milk (BNF, 1995b). Prospective studies, such as the Nurses' Health Study, have shown a high intake of *trans* fatty acids to increase risk of CHD (Oh *et al.* 2005, Hu *et al.* 1997) but current European diets are generally sufficiently low in these fatty acids not to warrant concern (Hulshof *et al.* 1999). In Britain, current intake is low, at 1.2% of energy (Henderson *et al.* 2003a) (Dietary Reference Value is 2% energy), whilst reductions in intake are less apparent in North America.

There have been reports of some interesting isomer-specific effects of CLA on the blood lipid profile in human subjects, however, findings have been inconsistent and this might be attributed to the variability of the dose level and/or the mix of CLA isomers used, particularly as results from animal studies show that specific isomers of CLA may be responsible for specific biological effects (Stanner, 2005). Unfavourable effects of a high dose of one of the CLA isomers (*t*10*c*12 CLA, 3.4g/day) has also been reported in relation to increased insulin resistance, oxidative stress and inflammatory biomarkers, and whilst such an intake is not consumed by diet alone, at present the effects of CLA on human health remain unclear (Tricon *et al.* 2005).

In the GISSI-Prevenzione Investigators 1999 trial, high doses of long-chain PUFAs from fish or supplements were given to patients who had already had a heart attack, and demonstrated a reduction in cardiac events (*e.g.* death, nonfatal MI and non-fatal stroke) (Burr *et al.* 1989). Prospective studies (*e.g.* the Nurses' Health Study) have also shown an inverse association between fish consumption and *n*-3 fatty acids and CHD deaths (Hu *et al.* 2002). Despite being present at low levels, particularly when compared with oil-rich fish, meat, primarily lean meat, contains medium (α-linolenic acid) and long-chain *n*-3 PUFAs (EPA, DPA and DHA) and is a significant source of these cardio-protective fatty acids for the average consumer.

The relative risk of both CHD and stroke increases as blood pressure rises. In a recent review of the effect of sodium on blood pressure, the Scientific Advisory Committee on Nutrition (SACN) in the UK concluded that although studies that have prospectively collected 24-hour urine (a good marker of sodium intake) suggest that a high salt (sodium chloride) intake has adverse effects on CVD mortality, there are insufficient reliable data on morbidity and premature mortality outcomes to reach clear conclusions (Scientific Advisory Committee on Nutrition, 2003). However, SACN concluded that reducing the average salt intake in Britain would confer significant public health benefits by contributing to a reduction in CVD burden. Similar recommendations have been made elsewhere (American Heart Association, 2000). Carcass meat contains very little sodium naturally, but salt is added to meat products for a variety of technical reasons.

Thus whilst red meat contains SFAs, a high intake of which can have adverse effects on CVD risk factors such as blood cholesterol levels, it also contains other fatty acids (*n*-3 PUFAs, MUFAs) and nutrients (*e.g.* B vitamins and selenium) that offer potential cardioprotective benefits. Processed meat products make a substantial contribution to total salt intake which is thought to influence blood pressure, a risk factor for CVD. To address this the meat industry in the UK has been working to reduce the salt content of meat products for some time (Matthews and Strong 2005).

Obesity

Meat-eaters have been shown to have a higher BMI than comparable vegetarians (Key *et al.*, 1999b); however, evidence of an association between meat consumption and obesity does not automatically indicate that there is a causal link. Furthermore there are problems with interpreting studies comparing meat eaters with vegetarians, as vegetarians tend to be more health-orientated generally *e.g.* consuming more fruit and vegetables and having higher levels of physical activity. Obesity is a complex disorder with a diverse range of causal factors and to identify one dietary factor as causal would be a gross oversimplification of a complex process.

Nevertheless, there is modest evidence that a high dietary fat to carbohydrate ratio in the diet is more likely to promote obesity development (British Nutrition Foundation 1999b). Meat makes a relatively high contribution to dietary fat intakes; a recent UK dietary survey indicated that meat and meat products contribute around 23% of total fat intake (Henderson *et al.* 2003a). However, with the progressive decline in the fat content of carcass meat, lean red meat can now contain as little as 2% fat. As dietary fat comes from a variety of sources, reducing the fat content of the diet *as a whole* (target recommendation 35% of food energy) is a key feature of health policy activities.

There is some evidence that it can be advantageous to include lean meat in weight loss diets, as high protein intakes have been found to lead to increased satiety (Stubbs, 1995). Halton and Hu (2004) recently conducted a systematic review of studies investigating the effects of high protein diets on thermogenesis, satiety, body weight and fat loss. Overall, they concluded that there is some evidence that diets higher in protein lead to increased weight loss and fat loss compared to diets lower in protein in the short-term (6-month period), but further longer-term studies are needed. Possible mechanisms to explain this effect include increased satiety from protein, decreased subsequent energy intake and the displacement of carbohydrate in higher protein diets. It seems likely that several of these mechanisms work together and are inter-related (Hu, 2005).

Type 2 Diabetes

The prevalence of type 2 diabetes is increasing rapidly worldwide and this is thought to be linked to the increasing prevalence of obesity. Currently an estimated 120 million people worldwide are affected by type 2 diabetes and the incidence has been predicted to double to 215 million by 2010. There are a number of risk factors for type 2 diabetes, the most important being genetic predisposition, obesity and physical activity level (British Nutrition Foundation 2004). Evidence from a small number of recent cohort studies in the US suggest that frequent consumption of processed meat (*e.g.* 5 times or more per week) may be associated with an increased risk of type 2 diabetes. However, to date there have been no intervention studies (the means of demonstrating cause and effect) and purported mechanisms are merely speculative. The evidence that exists points to any effect being linked with processed rather than lean red meat, and processed meat products can be high in fat. Hence the findings are in accord with current recommendations to reduce fat intake and to include lean meat in the diet, in moderation.

People with type 2 diabetes, like the general population, are recommended to follow a healthy balanced diet, low in fat (especially SFAs) and rich in fruit, vegetables and whole grain cereals, to maintain a healthy body weight and to stay physically active (British Nutrition Foundation 2004). There is no evidence to suggest that lean red meat cannot be recommended, in moderation, as part of a healthy balanced diet for people with type 2 diabetes. In fact, single-meal intervention studies suggest that an energy-restricted, high-protein, low-fat diet (that includes red meat) may actually help improve overall glucose control in type 2 diabetes (*e.g.* Gannon *et al.*,2003).

Conclusion

The main health benefits associated with eating red meat relate to its nutritional composition. Red meat contains high biological value protein and important micronutrients, all of which are essential for good health throughout life. The majority of the population in most developed countries consume meat and meat products, and therefore meat makes a significant contribution to nutrient intake for most individuals. In addition, meat can be a versatile food that adds variety to eating occasions and is enjoyed by many. Some people choose not to eat meat, for a variety of reasons, but as there is no evidence that a moderate intake of lean red meat has any negative effects on health, there is currently no real scientific justification for excluding it from the diet. Thus, as recommended in healthy eating advice around the world, lean red meat, consumed in moderation, can be promoted as part of a healthy balanced diet.

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