THE ROLE OF RED MEAT

in a healthy New Zealand diet

A summary of the evidence exploring red meat's unique package of nutrients which contribute to optimal health as part of a balanced diet and active lifestyle.

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SUMMARY

Historically, red meat has played a central role in the human diet.

Around 4 to 5 million years ago, it is believed the ancestral hominid line emerged from the receding forests to become bipedal open grassland dwellers, evolving to require higher-quality foods based around meat protein and fat.

This was accompanied by subsequent physiological and metabolic adaptations involving the development of a larger brain and a smaller gastro-intestinal tract.

Evidence from fossil stable isotope analysis demonstrates a growing reliance on consumption of meat as humans evolved.

Red meat continues to play an important role in the human diet today; it is an excellent source of protein and, trimmed of visible fat, is low in total fat and saturated fatty acids. It also makes a significant contribution to the monounsaturated and omega 3 fatty acids in our diet.

In addition, meat from ruminant animals, such as beef and lamb, provides conjugated linoleic acid (CLA), which has been found to have cancer preventive and immunomodulatory properties in animal models.

In terms of micronutrients, red meat (particularly beef and lamb) is an excellent source of bioavailable iron and zinc, and also provides selenium, vitamin D, and B vitamins, with red meat being one of our major sources of vitamin B_{12}. Red meat also contains bioactive compounds such as taurine, carnitine, creatine and some endogenous antioxidants.

Lean red meat has an important role to play in the diets of all age groups in New Zealand, providing nutrients that enable optimal growth and development in childhood as well as maintenance of health and well-being throughout adulthood and well into old age.

For those who exclude meat, careful consideration needs to be given to the nutritional adequacy of the diet as more restrictive diets are associated with a greater risk of deficiencies. In particular, vegans (who exclude all animal products) need to take extra care to ensure their nutritional needs are met.

The low fat and saturated fatty acid content of lean red meat makes it an ideal food to include as part of a heart-healthy, balanced diet.

The protein content may play a useful role in weight management due to its effect on appetite control, satiety and food craving. There is also emerging evidence that as dietary protein intake falls, energy intake increases. Due to the impact protein has on the glyacemic index of a meal, there is an important role in diabetic blood sugar control.

With respect to cancer, epidemiological and mechanistic data on associations between red meat and cancer are weak in magnitude and are inconsistent. Current average intakes of red meat in New Zealand are below the amount recommended by the World Cancer Research Fund (WCRF, 2007) of up to 500g cooked red meat per week.

Lean red meat had a central role in the diet of early man and continues to do so in modern times (Ruxton et al., 2013). It is consumed by nine out of ten New Zealanders once or more a week. Red meat provides a unique package of nutrients that make an important contribution to optimal health as part of a balanced diet and active lifestyle.

1. INTRODUCTION

In New Zealand, 94.5% of the adult population consume red meat (University of Otago & Ministry of Health, 2011). Among children, 95% consume an omnivorous diet (Parnell et al., 2003).

As the majority of New Zealanders consume meat, consideration of its contribution to nutritional intakes and its role in health and disease is important.

This report provides background information on human evolution and the increasing importance of meat consumption as humans have evolved. It reviews current scientific knowledge in terms of the nutritional content of red meat, its contribution to the diets of New Zealanders and its role in health and disease.

Some of the myths and misconceptions about meat are discussed in Appendix 1 and information about current farming practices in New Zealand, sustainability, and risk management at processor level are covered in Appendix 2.

The term 'red meat' in this report refers to beef, veal, lamb and mutton. For the purpose of this report, where meat is mentioned it refers to red meat flesh, which is defined as the skeletal muscle of beef, lamb, veal and mutton which includes any attached fat, connective tissue, rind, nerve, blood and blood vessels (FSANZ, 2012).

2. HUMAN EVOLUTION AND MEAT CONSUMPTION

Meat has played a central role in our diets throughout evolution and there is good evidence that over the last 2 million years the human ancestral line has been consuming increasing quantities of meat (Mann, 2000). The earliest evidence for scavenged meat goes back to the late Austalopithecines after early hominins were herbivores. In fact, it has been suggested that even mild and intermittent shortages of meat can have adverse consequences for energy and micronutrient-sensitive tissues such as the brain (Williams and Dunbar, 2013).

Not only have there been changes in cranio-dental features to enhance our ability to bite and tear animal flesh, but comparative gut morphology shows humans are truly omnivorous (Mann, 2007). In addition, fossil isotope ratios indicate consumption of a high-meat diet in early hominids, as early as 1.8 million years ago (Mann, 2000).

More recent human history, from archaeological records of around 40,000 years ago, shows the use of bone and antler tools such as spear tips and harpoons.

There is also evidence to suggest animal traps and bows and arrows were used subsequent to this time (Ulijaszek, 2002). Around 9,000 years ago the settling and growth of populations and the domestication of both plants and animals began (Biegert, 1975).

Primates in general and humans in particular, have larger brain sizes than would be expected for their body size, a phenomenon described as encephalisation. In humans, there has been a dramatic increase in brain size over the last 2-3 million years (Aiello & Wheeler, 1995).

The consumption of meat rich in fats (particularly the unsaturated fats) is one theory to be the factor responsible for the threefold increase in brain size over the last 4.5 million years (Chamberlain, 1996; Mann, 1998). It has been estimated that whenever it was ecologically possible, hunter-gatherers consumed 45-65% of their energy from animal foods, with protein providing 19-35% of energy at the expense of carbohydrates, which provided 22-40% of energy (Cordain et al., 2000). Another theory, the social brain hypothesis suggests brain size in primates is linked to the size of groups of which they live (Dunbar, 2009).

It has been suggested diets high in meat can be associated with high cholesterol levels and elevated risk of heart disease (Snowdon et al., 1984; Huijbregts et al., 1995; Menotti et al., 1999). However, a diet high in animal foods does not necessarily elicit unfavourable blood lipid profiles. An analysis of a type of hunter-gatherer diet by Cordain et al. in 2002 found that although 65% of energy was provided by animal foods, many hunter-gatherer societies are relatively free of the signs and symptoms of cardiovascular disease (CVD). More intense exercise and work patterns are likely to have provided pre-agricultural people with protection against CVD. In addition, qualitative differences in fat intake, including a higher intake of monounsaturates and polyunsaturates and a lower *n*-6:*n*-3 ratio, would have served to inhibit the development of cardiovascular disease among these populations.

Other dietary factors, such as a high intake of antioxidants, fibre, vitamins and phytochemicals and a low intake of salt and sugar, along with low levels of stress and no smoking, would further deter the development of cardiovascular disease.

Reverting to the diet and lifestyle of the hunter-gatherer has been shown to result in health benefits. A study of middle-aged, overweight, diabetic Aborigines in Australia, who reverted to their traditional hunter-gatherer diet for seven weeks, found improvements in all aspects of carbohydrate and lipid metabolism linked with insulin resistance (O'Dea, 1984). Despite the high contribution of animal foods to energy intake in this study (64%), the diet was low in total fat (13%) due to the very low fat content of the wild animals.

While there is no consensus on what the Palaeolithic diet is exactly, it is generally characterised by higher protein, less total fat, more essential fatty acids, lower sodium and higher fibre (Turner & Thompson, 2013).

It has been proposed that the relatively recent deviation from the Palaeolithic diet and lifestyle may be the basis of many, if not all, current diseases of civilisation (Kuipers et al., 2012), yet in some cases positive selection was so strong that in the 10,000 years since the beginning of Neolithic age, populations in Europe and East Africa evolved to use dairy beyond infancy (Tishkoff et al., 2006).

A recent randomised controlled trial of one Palaeolithic diet among 70 post-menopausal women (mean age 60 years) found strong effects on fat mass, body weight and abdominal obesity after 6 months, although there were no significant differences at 24 months (Mellberg et al, 2014). In this study, the Palaeolithic diet provided 30% of energy from protein, 40% from fat and 30% from carbohydrate; the diet was based on lean meat, fish, eggs, vegetables, fruits, berries, nuts, avocado, rapeseed oil and olive oil; the diet was high in monounsaturated and polyunsaturated fats.

In summary, meat has been a significant part of our diet for millions of years and still makes an important contribution today. A diet high in lean red meat has been shown to lower plasma cholesterol, contribute significantly to tissue *n*-3 fatty acids, and provides a good source of iron, zinc and vitamin B_{12} (Mann, 2000).

A Palaeolithic dietary pattern may be beneficial in terms of aiding weight loss, but further research is needed into the longer-term effects of this type of diet before firm recommendations can be made (Mellberg et al, 2014).

3. KEY NUTRIENTS IN BEEF AND LAMB

The primary components of meat are water, fat and protein. The proportions of these constituents can be highly variable, depending on the species and breed of animal, the age of the animal at slaughter, the season, and the types of grass and feed used. The amount of trimming of fat both before and after purchase, and the cooking method used will also influence the nutritional composition of the meat as eaten (BNF, 1999).

There are a number of valuable vitamins, minerals and trace elements in lean meat. In particular, red meat is an excellent source of iron and zinc, which are present in a highly bioavailable form. Red meat also provides a number of B vitamins, along with vitamin D, and offal is a good source of vitamin A.

A summary of the nutrients in lean beef and lamb can be found in Table 1.

Detailed background information on different nutrients and their role in the prevention of deficiency can be found in the National Health and Medical Research Council report *Nutrient Reference Values for Australia and New Zealand including Recommended Dietary Intakes* (NHMRC, 2006). This report also provides information on optimising diets to reduce chronic disease risk.

3.1. FAT

A small amount of fat can contribute to the palatability and flavour of meat. However, it is advisable to remove the visible fat from meat before eating to reduce overall fat content. Red meat cuts as sold have undoubtedly become leaner over the last 2 decades (Laugesen, 2005).

Since 1997, the red meat industry's Quality Mark has required the trimming of beef and lamb cuts to no more than 5mm external fat (see Appendix 2 for further information). This has ensured leaner cuts have become the norm.

TABLE 1: NUTRITIONAL COMPOSITION OF RAW, SEPARABLE LEAN BEEF AND LAMB (PER 100G)

Nutrient	Beef* (Assorted cuts)	Lamb* (Assorted cuts)	Adult NZ RDI**
Energy (kJ)	841	792	5,600-18,600
Protein (g)	30.7	27.4	46-81
Fat (g)	8.6	8.9	-
Thiamine (mg)	trace	trace	1.1-1.4
Riboflavin (mg)	trace	trace	1.1-1.6
Niacin (mg)	9.0	11.0	14-18
Vitamin B_6 mg)	0.22	0.18	1.3-2.0
Vitamin B_{12} µg)	1.6	1.8	2.4-2.8
Total folate (µg)	6.8	0	400-600
Sodium (mg)	40	68	460-920+
Potassium (mg)	280	320	2,800-3,800+
Calcium (mg)	6.1	15	1,000-1,300
Iron (mg)	2.6	1.8	8-27
Zinc (mg)	5.1	4.0	8-14
Selenium (µg)	3.3	6.3	60-75

*Sources: *Sivakumaran et al., 2014b; **NHMRC, 2006*
RDI is the Recommended Dietary Intake (the average daily dietary intake level sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a particular life stage and gender group).
+Adequate Intake (AI), used when a RDI cannot be determined.

A study into the impact of this initiative found the trimming of fat from red meat before sale (supported by virtually all butchers) resulted in 30% less fat and 65% less saturated fat than 20 years ago (Laugesen, 2005).

Data from the 2008/09 New Zealand Adult Nutrition Survey revealed that intake of total fat was 33.7% and 33.8% for men and women respectively (University of Otago & Ministry of Health, 2011), down from 40% in 1977 and 35% in the 1997 survey (Russell et al., 1999).

The same survey showed beef and veal contributed 4.8% to total fat intake and lamb and mutton contributed 2%, down from the previous survey of 8% of total fat intake from beef and lamb. Sausages and processed meats contributed 4%, and pies and pasties contributed 3.5% to fat intake.

The total fat and fatty acid content of selected beef and lamb cuts is shown in Table 2, where it is to be noted the saturated fat content is about 33% of total fat of lean cuts compared to over 50% in the fat trimmed from the meat.

3.1.1. SATURATED FATTY ACIDS (SFA)

Saturated fatty acids (SFA) are fully saturated with hydrogen and contain no double bond. They are the main types of fatty acids found in foods such as milk, cream, cheese, meat from most land animals, palm oil and coconut oil as well as in pies, biscuits, cakes and pastries (NHMRC, 2006).

Only around half the fat in meat is saturated (see Table 2). The rest is mainly monounsaturated fats, with small amounts of polyunsaturated fats, including some *n*-3 fatty acids. The main saturated fatty acids in meat are palmitic and stearic acid (Higgs, 1999); and stearic acid has almost no effect on blood cholesterol (FAO, 2010).

The density of saturated fatty acids in a 100g portion of lean meat is quite low (see Table 2). For example, one tablespoon of olive oil contains more saturated fat (2.3g) than two slices of lean roast silverside of beef (1.7g) (Sivakumaran et al., 2014). In the 2008/09 New Zealand Adult Nutrition Survey, the contribution to intake of saturated fat from beef and veal was 5% and 2.3% from lamb and mutton. (University of Otago & Ministry of Health, 2011). For more information on saturated fats and coronary heart disease, see section 8.1.1.

3.1.2. MONOUNSATURATED FATTY ACIDS (MUFA)

Monounsaturated fatty acids (MUFA) have one double bond; the main MUFA is oleic acid (NHMRC, 2006).

Monounsaturates have been found to help lower the amount of LDL cholesterol in the blood, while maintaining HDL blood cholesterol levels. This is likely to be a factor in the ability of Mediterranean diets, which are rich in monounsaturates, to protect against cardiovascular disease (BNF, 2005).

A significant proportion of the fatty acids in meat are monounsaturates (see Table 2), principally oleic acid (Higgs, 1999). In New Zealand, the contribution to intake of monounsaturated fat from beef and veal is 5.8% and 2.1% from lamb and mutton (University of Otago & Ministry of Health, 2011).

3.1.3. POLYUNSATURATED FATTY ACIDS (PUFA)

Polyunsaturated fatty acids (PUFA) contain two or more double bonds. There are two main types of PUFA: omega-3 and omega-6 (abbreviated as *n*-3 and *n*-6). The balance of *n*-3 and *n*-6 in the diet is thought to be important for health. High intakes of *n*-6 PUFA have been linked with a lower risk of coronary heart disease (CHD) and lower LDL-cholesterol levels (NHMRC, 2006; BNF, 2005). The *n*-3 PUFA have little effect on blood cholesterol, but reduce triglyceride levels and have a beneficial effect on blood clotting. In addition, experimental studies have shown *n*-3 PUFA modify inflammatory and immune reactions (Simopoulus, 2002).

Fish and seafood are the richest dietary sources of *n*-3 PUFA, with concentrations 5-15 times higher than meat (Howe et al., 2006); however meat is also likely to make a significant contribution to intakes of *n*-3 PUFA when the relative amounts eaten are considered. Australian data show meat, poultry and game contribute 43% to overall intakes of *n*-3 PUFA, with beef contributing 22.3% and lamb contributing 5.9% (Howe et al., 2006). Whilst this is high in percentage terms, it is still relatively low in absolute long chain *n*-3 amounts.

Meat from animals raised on grass, as in New Zealand, contains higher levels of *n*-3 PUFA than meat from animals raised on grain. One study found, for example, there was 2-4 times the amount of *n*-3 PUFA in beef from grass-fed animals (including 18:3) than in meat from concentrate-fed animals, except for 20:4 *n*-3 where there was 10 times the amount in the grass group (Enser et al., 1998). The same study found similar results for lamb from animals grazed on grass. Enser (1995) also showed lean grass-fed beef has a much higher amount of phospholipids, which are rich in *n*-3, particularly docosapentaenoic acid (22:5) and a source of choline.

A more recent study compared the effects of consuming red meat from either grass-fed or concentrate-fed animals, and found that dietary intakes, as well as plasma and platelet concentrations of long chain *n*-3 PUFA were significantly higher in those subjects who consumed the grass-fed animals (McAfee et al., 2011). The difference in intake of long chain *n*-3 PUFA between the groups that was attributable to the red meat consumed was estimated at 18mg/day.

A significant amount of the *n*-3 PUFA in meat are from docosapentaenoic acid (DPA), which is an intermediate in the production of docosahexaenoic acid (DHA) from eicosapentaenoic acid (EPA). DPA has been shown to be a more potent inhibitor of platelet aggregation than EPA or DHA (Akiba et al., 2000), and in the Kuopio Ischaemic Heart Disease Risk Factor Study, reduction in risk of acute coronary events correlated significantly with serum concentrations of DPA and DHA in individuals whose mercury status was low (Rissanen et al., 2000). Epidemiological data on DPA are, however, limited and more information is needed on the nutritional and health benefits of consumption of DPA (Howe et al., 2006).

Given the evidence linking EPA, DHA and DPA to health, it would seem prudent to encourage increased consumption of these fatty acids in the diet. An intake in the region of 0.4g/day for women and 0.6g/day for men is recommended (NHMRC, 2006). Overall, red meat in New Zealand could make an important contribution to intakes of *n*-3 PUFA, particularly in those who don't eat much fish (Knowles et al., 2004).

TABLE 2: TOTAL FAT AND FATTY ACID CONTENT OF LEAN COOKED BEEF AND LAMB (PER AVERAGE 100G SERVING)

Meat Cut	Total fat (g)	SFA (g)	MUFA (g)	PUFA (g)
Lean beef, cooked, assorted cuts	8.6	2.9	3.1	0.4
Beef mince, premium, simmered	3.3	1.2	0.9	0.2
Beef silverside, lean, roasted	5.0	1.7	1.8	0.3
Beef topside, lean, braised	7.3	2.5	2.6	0.4
Lean lamb, cooked, assorted cuts	8.9	3.2	2.3	0.5
Lamb leg, lean, roasted,	6.4	2.1	1.8	0.4
Lamb, rump, lean, roasted	5.3	1.8	1.3	0.3

Source: Sivakumaran et al., 2014b

3.1.4. TRANS FATTY ACIDS

Trans fatty acids (TFAs) are unsaturated fatty acids that have at least one double bond in the *trans* configuration. There is good evidence TFAs have a more adverse effect on cardiovascular disease risk than saturated fatty acids (FAO, 2010), although, quantitatively TFAs constitute a much smaller proportion of the diet than saturated fatty acids (NHMRC, 2006). Most of the *trans* fat in the diet is found in margarines and products such as cakes, biscuits and pastries. Some *trans* fats can also occur naturally at low levels in ruminant animal foods, formed as a result of biohydrogenation by rumen bacteria. However, the predominant ruminant TFA is vaccenic acid (Turpeinen et al., 2002), which has not been associated with coronary heart disease (Willett et al., 1993). There is an average of 0.2g *trans* fat in lean cuts of beef and lamb (New Zealand FOODfiles, 2013).

The World Health Organisation has recommended TFAs contribute no more than 1% of total dietary energy (WHO, 2003). In New Zealand, current intakes are around 0.6% of total dietary energy (FSANZ, 2014) which is due to the removal of partially hydrogenated fat from margarines by manufacturers a decade ago. It is recommended saturated fatty acids and TFAs together contribute no more than 8-10% of total energy (NHMRC, 2006).

3.1.5. CONJUGATED LINOLEIC ACID

The term conjugated linoleic acid (CLA) generally refers to mixtures of positional and geometric conjugated isomers of linoleic acid. The principle dietary form of CLA is the cis-9, *trans*-11 isomer (Pariza et al., 2000), which provides over 90% of our intake (Nakamura et al., 2008). CLA has been shown in animal studies to inhibit carcinogenesis and atherosclerosis, enhance immunologic function, affect body composition change (reducing fat gain and enhancing lean body mass gain), and stimulate growth (Pariza et al., 2000). CLA has also been found to modulate immune function in humans (O'Shea et al., 2004). However, studies in humans into the effects of CLA are generally less conclusive than animal studies, with conflicting and inconsistent findings (Plourde et al., 2008; Nakamura et al., 2008) as dosages of around 3g/day were required.

The highest levels of dietary CLA are found in the meat and milk from ruminant animals (Nakamura et al., 2008). The method of feeding may affect the levels of CLA present in the meat. For example, beef from pasture-fed cattle may have a higher CLA content than beef from silage or grain-fed cattle (Mir et al., 2004). CLA in meat is located in the interstitial, non-visible fat, evenly distributed along the muscle fibres, as well as in the subcutaneous deposits (Eynard & Lopez, 2003), whereas visible fats are often and easily discarded, interstitial fats will be eaten. Thus, lean meat could potentially make an important contribution to the human intake of CLA.

The current dietary intake of CLA in Western populations is too low to provide the beneficial effects seen in animal studies (Turpeinen et al., 2002) and further research is needed into the potential benefits of dietary sources of CLA. In particular, investigations are needed to develop an understanding of the molecular action of CLA isomers and their potential use in chronic disease therapy (Nakamura et al., 2008).

In addition, a significant portion of the lipids in lean meat are in the form of phospholipids which are a source of choline, which contributes to normal homocysteine and fat metabolism.

3.2 PROTEIN

Red meat is an excellent source of high biological value protein; the protein is highly digestible and provides all essential amino acids (lysine, threonine, methionine, phenylalanine, tryptophan, leucine, isoleucine and valine) with no limiting amino acids (Williams, 2007). A 100g portion of cooked lean beef or lamb provides around 25-30g of protein (see Table 1).

On average, beef and veal contribute 7.8% to protein intakes in New Zealand, lamb and mutton contribute 2% (University of Otago & Ministry of Health, 2011).

Diets with as little as 10% energy from protein are adequate to meet basic protein requirements, but intakes above 15% energy from protein appear to be required for ensuring adequate intakes of micronutrients.

Evidence is accumulating that increasing intake of high quality protein to a level above the recommended intake may be beneficial during weight loss (see section 8.3).

However, an upper limit of 25% energy from protein has been suggested until more is known about the long-term effects of a high-protein diet (NHMRC, 2006).

3.3. MICRONUTRIENTS

3.3.1. IRON

Iron is needed for the production of a number of proteins in the body, including haemoglobin, myoglobin, cytochromes and enzymes involved in redox reactions. Iron is also important for early brain development and for supporting a healthy immune system.

Iron is present in food in two forms – haem and non-haem. Haem iron (found in meat and fish) is more bioavailable than non-haem iron, with conservative estimates that 25% is absorbed (Hallberg & Rossander-Hulthen, 1991). Non-haem iron (found in meat, legumes, nuts, cereals, some fruits and dark green vegetables such as spinach) is less bioavailable and absorption is influenced by other dietary components. For example, foods containing vitamin C can increase absorption of non-haem iron. In contrast, foods containing phytates (found in legumes and wholegrain cereals) can inhibit non-haem iron absorption. Absorption of iron from vegetarian diets has been estimated to be around 10% (Institute of Medicine Panel on Micronutrients, 2001) and it has been suggested there can be a 10-fold difference in the absorption of iron from different meals with a similar iron content (Hallberg & Hulthen, 2000). Absorption of iron is about 18% from a mixed diet, so iron requirements for vegetarians, who rely on non-haem sources, will be about 80% higher than for those who eat meat (NHMRC, 2006).

Beef and lamb are among the richest sources of bioavailable iron in the diet and, in addition, meat enhances the absorption of non-haem iron from foods eaten at the same time. The nature of the enhancing effect is thought to be related primarily to the muscle proteins (Hurrell et al., 2006). In New Zealand, beef and veal have been found to contribute 7% to our total iron intake and lamb and mutton provide a further 1.5% (University of Otago & Ministry of Health, 2011). The actual contribution of meat to iron intake is much greater, however, owing to the higher proportion of iron absorbed.

Inadequate intakes of iron can lead to varying degrees of deficiency; from low iron stores (indicated by low serum ferritin and reduced iron-binding capacity) to iron-deficiency anaemia (low haemoglobin and haematocrit as well as reduced mean corpuscular haemoglobin and volume) (NHMRC, 2006). The recommended intake of iron in different population groups is shown in Table 3.

Iron deficiency is the most common and widespread nutritional disorder in the world. As well as affecting a large number of children and women in developing countries, it is one of only a few nutrient deficiencies which are also significantly prevalent in developed countries such as New Zealand. The numbers are staggering: 2 billion people – over 30% of the world's population – are anaemic (WHO, 2014), with a substantial proportion of these anaemias resulting from iron deficiency.

The adverse effects of iron deficiency anaemia include poor cognitive development, fatigue, reduced tolerance to work, and decreased aerobic capacity. Iron deficiency anaemia can also have an impact on behaviour. In infants, iron deficiency anaemia has been associated with maintaining closer contact with caregivers, showing less pleasure and delight, being more wary, hesitant and easily tired, being less attentive to instructions and being less playful (Lozoff et al., 1998). Severe, chronic iron deficiency anaemia in infancy has also been associated with reduced mental and motor functioning, and continued developmental and behavioural risk more than 10 years after iron treatment (Lozoff et al., 2000).

Approximately 4% (Soh et al., 2004) to 6% (Grant et al., 2007b) of infants and toddlers in New Zealand have iron deficiency anaemia. However, non-anaemic iron deficiency is considerably more common than iron deficiency anaemia in New Zealand infants and young children (Soh et al., 2004), and may be associated with subtle negative effects on cognitive function and fatigue, as well as an increased risk of developing iron deficiency anaemia if the infant is exposed to a physiological challenge such as rapid growth, infection, or injury.

A study in Auckland children aged 6-24 months found 14% were iron deficient, with the occurrence among Māori and Pacific Island children even higher at 20% and 17% respectively (Grant et al., 2007b). Iron intake was less than the estimated average requirement (EAR) for 25% of the infants. Not meeting the EAR increased the risk of iron deficiency for children aged 6-11 months (relative risk (RR) = 18.45, 95% confidence interval [CI]: 3.24-100.00) and 12-23 months (RR = 4.95, 95% CI: 1.59-15.41). In comparison with New Zealand Europeans, Pacific children had a greater daily iron intake ($p = 0.04$) and obtained a larger proportion of iron from meat and meat dishes ($p = 0.02$) (Wall et al., 2008).

Iron requirements in the first year of life are greater than at any other time due to rapid growth and blood volume expansion (Grant et al., 2007a). The depletion of iron stores accrued *in utero*, and increased demands for growth, mean that after six months of age infants depend on complementary foods to provide iron (Ministry of Health, 2008a). Meat has been found to play an important role as a complementary food. For example, the addition of powdered red meat to a weaning gruel has been shown to markedly increase total iron absorption (Hallberg et al., 2003). Puréed meat can be introduced once an infant is around 6 months of age. Given the risk of iron deficiency in infants and young children, it has been suggested public health campaigns should encourage adequate meat intake to help reduce the problem (Mira et al., 1996).

The importance of both meat and fortified milk for providing iron in the diets of toddlers was demonstrated in a New Zealand trial. The trial assessed the effect of increased red meat consumption, or the use of iron-fortified milk, for improving iron status in healthy non-anaemic toddlers aged 12-20 months (Szymlek-Gay et al., 2009).

In this 20 week randomised placebo-controlled trial, toddlers were assigned to either a red meat group (encouraged to consume approximately 2.6mg iron from red meat dishes daily), a fortified milk group (toddlers' regular milk was replaced with iron-fortified milk containing 1.5mg iron per 100mls), or a control group (toddlers' regular milk was replaced with a non-iron-fortified milk containing 0.01mg iron per 100mls). Whereas serum ferritin tended to decrease in the control group, it increased by 44% in the fortified milk group, and did not change in the red meat group. The authors concluded that iron-fortified milk can increase iron stores in healthy non-anaemic toddlers and red meat can prevent their decline (Szymlek-Gay, 2009).

Iron deficiency is also prevalent in Auckland high school students (Schaaf et al., 2000), particularly in girls, where iron deficiency and anaemia were each ten times more common (9.6% and 8.7% respectively) than in boys (0.8% and 0.7%). In females, iron deficiency was two to three times more common and anaemia was three to four times more common in Māori, Pacific Island and Asian adolescents compared with Europeans. Iron deficiency in this study was defined as any two or more of the following: serum ferritin less than 12μg/L, iron saturation less than 14%, or red blood cell distribution width greater than 14.5%. Anaemia was defined as haemoglobin less than 120g/L for females and less than 130g/L for males. The level of iron deficiency and anaemia in this study was higher than that reported in an earlier Dunedin longitudinal survey (Fawcett et al., 1998), which found the prevalence of iron deficiency (ferritin less than 12μg/L) at age 21 was 0.24% in men and 6.7% in women. The higher prevalence in the Auckland study is likely to be due to the different age group studied; adolescent girls have higher requirements for iron due to growth super-imposed on menstrual losses.

Concern has also been expressed in relation to the sub-optimal iron status of women of childbearing age in New Zealand. One study (Ferguson et al., 2001) estimated that the prevalence of sub-optimal iron status among 15-49 year old women was between 7% (serum ferritin less than 12μg/L) and 13% (serum ferritin less than 16μg/L). The authors stated that this situation is unacceptable given the negative consequences of even mild iron deficiency. The latest New Zealand Adult Nutrition Survey found that from 1997 to 2008/09 the prevalence of iron deficiency in females had increased from 2.9% to 7.2%. After adjusting for age and ethnicity, there was also an increase in the prevalence of low iron stores in females (University of Otago & Ministry of Health, 2011). For certain high-risk sub-groups (for example vegetarians, athletes, pregnant women, Pacific people and Māori), the prevalence of iron deficiency and iron deficiency anaemia is often much higher (Gibson et al., 2002).

A further study in pre-menopausal women in Auckland showed that, for women who had children, following a dietary pattern that was higher in meat and vegetables was associated with a 25% lower risk of sub-optimal iron status (Beck et al., 2014).

Pregnant women in particular are vulnerable to iron deficiency, as requirements are significantly increased to meet the needs of the growing foetus as well as increased maternal blood volume.

An iron-rich diet, which includes the regular consumption of red meat, chicken and fish, has been recommended (Grant et al., 2007a). Non-haem sources of iron such as grains, cereals, legumes and eggs should also be encouraged along with foods containing vitamin C to enhance absorption.

TABLE 3: RECOMMENDED DIETARY INTAKE FOR IRON FOR POPULATION GROUPS PER DAY

Population Group	RDI* (mg/day)
Infants (0-6 months)+	0.2 (AI**)
Infants (7-12 months)	11
Children (1-3 years)	9
Children (4-8 years)	10
Children (9-13 years)	8
Boys (14-18 years)	11
Girls (14-18 years)	15
Women (19-50 years)	18
Pregnant women	27
Breastfeeding women++	9-10
Women over 50 years	8
Men over 19 years	8

**RDI is the Recommended Dietary Intake (the average daily dietary intake level sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a particular life stage and gender group).*
***AI is the Adequate Intake, used when a RDI cannot be determined.*
+ Amount normally received from breast milk.
++ Assumes menstruation does not resume until after 6 months of breastfeeding.

Source: NHMRC, 2006

In cases of iron deficiency anaemia, iron supplementation is accepted as the most appropriate method of treatment. However, a New Zealand study investigated whether dietary treatment of non-anaemic iron deficiency could improve iron status in pre-menopausal Dunedin women. The study found that dietary intervention involving increased intakes of both haem iron (from flesh food) and enhancers of iron absorption (such as vitamin C), along with a decrease in intake of inhibitors of iron absorption (such as phytic acid), may improve the iron status of pre-menopausal women with low iron stores (Heath et al., 2001). Although the changes in iron status were less with dietary intervention than with supplements, in motivated women with low iron stores, dietary intervention may be an appropriate first-line treatment as long as they are monitored to ensure the treatment has been effective.

Prevention and treatment of iron deficiency among vulnerable groups within New Zealand is an important public health issue. In particular, we need to ensure optimal intakes of iron among groups such as infants, children, adolescents and pregnant women.

3.3.2. ZINC

Zinc is a component of various enzymes that help maintain the structural integrity of proteins and regulate gene expression (NHMRC, 2006). It is also known to play a central role in the immune system, with zinc deprivation leading to an increased susceptibility to pathogens because of impaired immune response (Shankar & Prasad, 1998). Zinc deficiency can also lead to impaired growth and adverse pregnancy outcomes (NHMRC, 2006).

Those at increased risk of zinc deficiency include older people, vegetarians and people with renal insufficiency (Ibs & Rink, 2003). Zinc deficiency has also been found among New Zealand school children; the 2002 Children's Nutrition Survey (Parnell et al, 2003) found 16% of children had low serum zinc concentrations (21% of males and 10% of females).

Further analysis of data from the 2002 Children's Nutrition Survey by Gibson et al. (2011) found that among Pacific children aged 5-15 years, the prevalence of low serum zinc concentrations was 21%, compared with 16% of Māori children and 15% of European children. In this study, children derived 23% of their zinc intakes from meat, poultry and fish.

It has been suggested that pre-school children may be at even higher risk of zinc deficiency. A recent intervention study found that at baseline 38% of toddlers (12-20 months of age) had low serum zinc concentrations despite seemingly adequate zinc intakes (Morgan et al., 2010). However, researchers in this study found that providing either red meat or fortified milk did not improve zinc status despite increasing zinc intakes.

New Zealand women have also been found to be at risk of zinc deficiency. A study into the zinc status of pre-menopausal Dunedin women found zinc status was lower than had been found in earlier studies (Gibson et al., 2001). It is suggested that changes over time in food selection patterns may account for this change. An example would be the decline in consumption of flesh foods – specifically beef and lamb, which are rich sources of bioavailable zinc. Certainly, in this study, the women who included red meat in their diet had a superior biochemical zinc status to those who avoided eating red meat.

The recent New Zealand Adult Nutrition Survey 2008/09 estimated that the prevalence of inadequate zinc intake was 24.7% (males 39.1%, females 11.2%). The highest prevalence was among older males aged 71+ years (89.7%) although these data should be interpreted with caution as the EAR may be set too high, and biochemical zinc status was not determined (University of Otago & Ministry of Health, 2011). An earlier study into the zinc status of Dunedin women aged 70 to 80 years old found 12% had low serum zinc levels (de Jong et al., 2001) and the authors concluded that promotion of nutrient-dense foods or trace element supplements for New Zealand seniors should be considered.

Although zinc is widely distributed in foods, meat, fish and poultry are major contributors, with cereals and dairy foods also providing substantial amounts (NHMRC, 2006). Beef and lamb in particular are among the richest dietary sources of zinc, with a 100g portion providing at least a quarter of adult requirements (see Table 1).

3.3.3. SELENIUM

Selenium is an integral part of glutathione peroxidase, an enzyme that protects against oxidative damage (NHMRC, 2006). Selenium is also important for the production of other key selenoproteins such as iodothyronine deiodinase (Arthur et al., 1999). Dietary selenium is essential for the efficient operation of many aspects of the immune system (Arthur et al., 2003; Broome et al., 2004) and for optimal thyroid hormone metabolism (Arthur et al., 1999). It may also be anti-carcinogenic (Combs, 2005). Intakes of selenium higher than the recommended intake may be required for protection against cancer and may have other health benefits. However, there is an urgent need for more large scale trials to assess any such beneficial effects and to estimate the level of selenium intake that is protective (Thomson, 2004a).

Overt deficiency of selenium in humans is rare but is seen as Keshan disease, an endemic cardiomyopathy in adolescent or pre-adolescent years in low selenium areas of China (Yang et al., 1988). More marginal deficiency may contribute to reduced immune function, some cancers and viral diseases (Broome et al., 2004).

The New Zealand Adult Nutrition Survey 2008/09 (University of Otago & Ministry of Health, 2011) found that among adults, selenium is provided by meat and meat products (15.1%), bread (15.1%), fish and seafood (11.6%) and poultry (9.6%). Analysis of data from the 2002 Children's Nutrition Survey showed that among children aged 5-14 years, selenium was provided by bread and grains (33%), meat (14.8%), poultry (11.2%), and fish and seafood (8.6%) (Thomson et al., 2007).

Regional differences in selenium intake in New Zealand were observed in the Children's National Nutrition Survey (Thomson et al., 2007). Analysis of the selenium status of children aged 5-14 years showed children in the upper North Island had mean serum selenium concentrations higher than those in the lower North Island and South Island. Younger children had lower selenium intakes than older children (Thomson et al., 2007). These differences have been partly attributed to the different levels of selenium found in bread, since the selenium content of bread is lower in the South Island than the North Island where higher selenium wheat from Australia is used. Another reason for the differences is the high fish and poultry intakes of Pacific children, of whom there was a higher proportion in the north of the North Island (60%) compared with the lower North Island (18%) and the South Island (11%). As a whole, our children fall in the middle of the range of international serum selenium concentrations. However, the selenium status of South Island children is among the lowest values reported internationally (Thomson et al., 2007).

Pregnant and breastfeeding women may be at risk of low selenium concentrations due to the increased selenium demands of the growing foetus and the increased demands of lactation. In addition, infancy is a vulnerable time, with rapid growth and development also leading to increased selenium requirements. A study of South Island children, aged 6-24 months, and their mothers, found dietary selenium intakes were below recommended levels (McLachlan et al., 2004) with intakes of 7.9 + 6.2μg/d in infants; 13.7 + 8.4μg/d in toddlers and 38 + 25μg/d in mothers.

The low intakes were reflected in blood selenium concentrations, which were at the lower end of international levels. The authors recommend dietary strategies to improve selenium intakes are implemented, for example, the inclusion of selenium-rich foods such as fish, meat and unrefined cereals.

The last New Zealand Adult Nutrition Survey 2008/09 estimated the prevalence of inadequate selenium intake was 45% (males 32%, females 58%). Females aged 15-18 years had a consistently high prevalence of inadequate intakes (over 70%) across all ethnic groups (University of Otago & Ministry of Health, 2011).

Overall, the selenium status of the New Zealand population has been increasing and continues to do so. This is due to some extent to the increase in selenium concentration of meat, but also to the increase in contribution of imported foods to our diet (Thomson, 2004b).

3.3.4. VITAMIN A

Vitamin A is a fat-soluble vitamin, which helps maintain normal reproduction, vision and immune function (NHMRC, 2006). The term vitamin A includes retinol from animal sources, and pro-vitamin A carotenoids, such as beta-carotene, which are precursors of vitamin A.

In New Zealand, 17.2% of the population have been found to have inadequate intakes of vitamin A, with a higher prevalence among younger people aged 15-18 years; 37.5% of males and 27.4% of females (University of Otago & Ministry of Health, 2011). Lower intakes of beta-carotene among younger people contributed to their inadequate intakes.

Carcass meat contains little vitamin A, but liver is a particularly good source of this vitamin in the form of retinol. Chronic intake of large amounts of retinol over time can be toxic and pregnant women should limit their intake of liver as vitamin A can be teratogenic (ie can cause defects in the growing foetus). In some countries, pregnant women are advised to avoid liver altogether; however, in New Zealand, animal feeding practices are different and levels of vitamin A in liver are likely to be lower. The Ministry of Health in New Zealand advises up to 100g of liver may be consumed per week during pregnancy, although liver pâté is not recommended as there is a risk of food-borne illness such as listeriosis (Ministry of Health, 2006a). No more than 10g of liver or pâté per week should be offered to children aged 1-3 years (NHMRC, 2006; Ministry of Health, 2008).

3.3.5. B VITAMINS

Red meat is an excellent source of vitamin B_{12}, which is only found naturally in foods of animal and microbial origin. Throughout life, the dietary supply of vitamin B_{12} and other methyl donors are essential for normal growth, development and function and is an essential nutrient for one carbon metabolic pathways. It is key for protein, fat and carbohydrate metabolism including the synthesis of fatty acids in myelin in the nervous system, and the synthesis and stability of deoxyribose nucleic acid conjunction with folate, for DNA synthesis (Stabler et al., 2013; Rush et al., 2014). Ensuring an adequate intake of vitamin B_{12} particularly in pregnancy and lactation is essential for optimising health of the offspring. A 100g portion of cooked beef or lamb provides almost the entire daily requirement for vitamin B_{12} (see Table 1). For vegans, who avoid all animal products, fortified foods or supplements will be necessary to provide adequate B_{12} (see section 4).

A 100g serving of beef or lamb also provides around half the daily requirement for niacin, along with some thiamine, riboflavin and vitamin B_6, as shown in Table 1. These B vitamins are important for numerous metabolic functions in the body, particularly as their respective co-enzyme forms, in energy metabolism.

3.3.6. VITAMIN D

The main function of vitamin D is to help maintain plasma calcium concentrations by enhancing the absorption of calcium in the small intestine and controlling urinary losses. Over the past decade, deficiency of this vitamin has been associated with higher risk of multiple sclerosis and poorer immune function (Harandi et al, 2014) and prevention of diabetes (Harinarayan, 2014) and some cancers (Ananthakrishnan et al, 2014).

Vitamin D status is generally maintained by the exposure of skin to sunlight. Where exposure to sunlight is inadequate, dietary sources of vitamin D become important. Sub-optimal vitamin D status is associated with low bone mineral density and the risk of osteoporosis later in life (Holick & Chen, 2008).

A high prevalence of vitamin D insufficiency was found in an analysis of the 2002 National Children's Nutrition Survey; with 4% of New Zealand children aged 5-14 years vitamin D deficient (<17.5nmol/L) and 31% vitamin D insufficient (<37.5nmol/L) (Rockell et al., 2005). The children studied had a mean serum 25-hydroxyvitamin D concentration of 50nmol/L, with mean concentrations in sub-groups ranging from 32nmol/L in Pacific girls aged 11-14 years, to 62nmol/L in New Zealand European and other boys aged 5-6 years. Children of Māori and Pacific ethnicity may be at particular risk of low vitamin D status because of low vitamin D intakes, New Zealand's high latitude (35-47°S) and skin colour (Rockell et al., 2005).

New Zealand adolescents and adults have also been found to be at risk of vitamin D insufficiency (Rockell et al., 2006). Analysis of serum 25-hydroxyvitamin D levels using data from the 2008/09 New Zealand Adult Nutrition Survey found 4.9% were vitamin D deficient (<25nmol/L) including 0.2% with severe deficiency (<12.5nmol/L), and one in four adults (27.1%) were below the recommended level of vitamin D, but did not have vitamin D deficiency. The prevalence of vitamin D insufficiency was higher among Pacific adults who were 2.3 times as likely to have vitamin D deficiency as non-Pacific adults.

A study of elderly Dunedin women also found vitamin D deficiency was common, particularly in women over 70 years of age, who had a high bone fracture risk (McAuley et al., 1997). Deficiency was most marked in winter months.

Red meat provides vitamin D. A study into the vitamin D content of beef and lamb found them to be a source of both vitamin D3 and its active metabolite 25-hydroxyvitamin D3 (Purchas et al., 2007). 25-hydroxyvitamin D3 is suggested to have 1.5 to 5 times the activity of vitamin D3, and the authors of this study estimate (assuming 1µg of 25-hydroxyvitamin D3 is equivalent to 3µg of vitamin D3) that, on average, 100g of beef striploin would contain 1.2µg of total vitamin D3 and 100g of cooked lamb leg steak would contain 2.6µg.

Current FoodFILES data shows an average of 0.14ug/100g vitamin D3 for lean, raw beef cuts and 0.04ug/100g vitamin D3 for lean, raw lamb cuts (Sivakumaran et al; 2014a).

Although this is a small amount compared to the amount needed (adequate intake of 5-10ug/day in adults under 70 years) to improve the vitamin D status of New Zealanders to optimal levels, there is some interest in determining whether meat has a role to play in providing vitamin D. A study by Crowe et al (2011) for example, found that plasma 25 (OH) D3 concentrations were lower in vegetarians and vegans than in meat and fish eaters. These results do need confirmation through further research (Glossmann, 2011), particularly as the vitamin D content of meat may be variable and dependant on the animal feed and exposure of the animal to sunlight.

3.3 BIOACTIVE SUBSTANCES

In addition to the essential nutrients, meat also provides a number of bioactive substances (Williams, 2007). Meat is a rich source of taurine, an amino acid that may be important during lactation and times of immune challenge, and may offer protection against oxidative stress. Meat also provides carnitine, which transports long chain fatty acids across the inner mitochondrial membranes to produce energy during exercise; requirements for carnitine may be increased in pregnancy and after strenuous exercise. Red meat is the principle human dietary source of creatine, which plays a role in energy metabolism. Meat is also a source of a number of endogenous antioxidants, for example ubiquinone, glutathione, lipoic acid, spermine, carnosine and anserine.

4. NUTRITIONAL IMPLICATIONS OF A MEATLESS DIET

A diet that excludes meat can be nutritionally adequate, but if an increasing number of foods are excluded it becomes important to plan the diet carefully to ensure nutrient needs are met. Intakes of iron, zinc and vitamin B_{12} need careful consideration – especially for vegans.

Vitamin B_{12} is of notable concern as it is only found naturally in foods of animal origin (see section 3.3.5). South Asian vegetarian women living in New Zealand have been found to have low serum B_{12} status (Gammon et al., 2012) and research into pre-adolescent Indian migrant girls in New Zealand has shown asymptomatic B_{12} deficiency (Rush et al., 2009).

Vegans are at particular risk of deficiency (Mann et al., 1999) as all animal foods are excluded from the diet. Among adults, a diet devoid of vitamin B_{12} may not lead to symptoms of deficiency for many years as most of us have significant body stores. In contrast, newborn infants have only small body stores and breastfed infants of unsupplemented vegan mothers may be at particular risk. One case study, for example, found a 14-month old boy who was exclusively breastfeed until 9 months of age had severe vitamin B_{12} deficiency caused by his mother's, presumably unsupplemented, vegan diet. Supplemental B_{12} rapidly improved haematological and neurological symptoms, although cognitive and language development remained seriously delayed at the age of two years (von Schenck, 1997).

Vegan mothers who are breastfeeding need to ensure an adequate intake of vitamin B_{12} and it is advised they supplement their diet to the recommended level during pregnancy and lactation (NHMRC, 2006). For vegan infants who are not breastfed, an appropriate soy-based infant formula should be used. Once a vegan infant has started to consume complementary foods, it is important to ensure a daily intake of vitamin B_{12}, with fortified foods or a supplement (Ministry of Health, 2008a).

Diets that exclude animal foods also have the potential to have low iron and zinc bioavailability. Eliminating meat, along with increasing intake of phytate-containing legumes and whole grains, reduces the absorption of both iron and zinc (Hunt, 2003) and a higher intake of these nutrients will be required in order to meet nutritional requirements. Vegetarians need iron intakes about 80% higher than non-vegetarians (NHMRC, 2006), and zinc intakes about 50% higher – particularly vegans (Hunt, 2003; NHMRC, 2006).

5. FOOD AND NUTRITION GUIDELINES IN NEW ZEALAND

The majority of New Zealanders consume meat, and as meat is such a nutrient-dense food it can be particularly useful in the diets of population groups with high nutrient needs. It is recommended we include 1-2 servings a day of iron-containing foods in our diet. For recommended serving sizes, see Table 4.

5.1 INFANTS AND TODDLERS

Lean meat can make an important contribution to the diets of infants and toddlers, providing protein, vitamins and minerals, in particular iron and zinc, which are present in a highly bioavailable form (see sections 3.3.1 and 3.3.2). Once an infant is around six months of age, puréed meat can be added to the diet with finely chopped, tender meat being introduced as swallowing develops (Ministry of Health, 2008a). Iron-fortified infant cereals can be introduced from 6 months and foods containing vitamin C (eg fruits and vegetables) should be offered with meals and snacks, to assist in non-haem iron absorption. If an infant is not breast-fed, it is important to use an iron-fortified infant formula until 12 months of age. Drinks containing iron inhibitors such as tea and coffee should be avoided by young children. Overall, it is important to offer a wide variety of foods from the different food groups to ensure nutritional needs are met during this period of rapid growth and development.

5.2 CHILDREN AND YOUNG PEOPLE (2-18 YEARS OLD)

Nutritional needs are highest during rapid growth, for example during early childhood and during the adolescent growth spurt; iron needs are particularly high in menstruating girls (Ministry of Health, 2012).

Ensuring optimal iron and zinc intake remains important among children and young people. New Zealand adolescent girls, especially those of Māori or Pacific ethnicity are at greatest risk of iron deficiency anaemia; young children are also at risk.

To ensure adequate iron intakes, it is recommended animal foods should be included in the diet, for example meat, poultry, fish and seafood along with plant foods such as wholegrain breads, cereals vegetables, legumes, nuts and fruit which provide non-haem iron. Eating foods rich in vitamin C will help to enhance absorption of non-haem iron; children and young people should also avoid drinking tea with meals. At least 1-2 servings a day of iron-containing foods should be provided in the diets of children and young people. Lean meat, poultry, fish and shellfish are also good bioavailable sources of zinc (Ministry of Health, 2012).

5.3 HEALTHY ADULTS

The Ministry of Health's Food and Nutrition Guidelines for Healthy Adults recommends maintaining a healthy weight, eating well, and being physically active every day. A variety of foods from the four main food groups should also be included daily (vegetables and fruits; breads and cereals; milk and milk products; and lean meat, poultry, seafood, eggs or alternatives). In addition, we are advised to choose foods with minimal fat, sugar and salt, to drink plenty of liquids (especially water) and to limit alcohol intake (Ministry of Health, 2003). At least one serving a day is recommended from the meat and alternatives group to provide protein, B vitamins, iron, zinc, magnesium, copper, potassium, phosphorus and selenium.

5.4 PREGNANT AND BREASTFEEDING WOMEN

Iron requirements increase significantly during pregnancy (see Table 3). However, routine iron supplements are not recommended in New Zealand as the proportion of iron absorbed from food increases in response to the increased need. They should only be given after diagnosis of iron deficiency anaemia. Iron requirements during breastfeeding are substantially lower than in pregnancy while women are not menstruating.

To ensure adequate iron intake among pregnant and breastfeeding women, dietary strategies should include consumption of at least two servings of iron-containing foods a day (Ministry of Health, 2006a). Beef and lamb can make a particularly useful contribution to intakes of iron as they are rich sources of bioavailable iron. Other sources of iron are poultry, seafood, eggs, nuts and seeds, and legumes. Monitoring of iron status throughout pregnancy is important to identify current or potential iron deficiency. All women should receive advice on dietary sources of iron and factors affecting iron absorption, in order to avoid iron deficiency.

Pregnant vegetarian and vegan women may find it difficult to meet iron requirements and should be encouraged to consume plenty of iron-containing plant-based foods along with foods rich in vitamin C and to have blood levels of iron checked regularly.

Pregnant and breastfeeding women should be advised to consume a variety of nutritious foods from the main food groups to ensure adequate nutritional status.

5.5 OLDER PEOPLE

Among older people in New Zealand (aged 65 years and older) nutrition deserves special attention as nutritious food is essential for good health and can prevent malnutrition, support physical function, reduce the risk of chronic disease, support mental health and prevent disability.

Older people should include a variety of foods in the diet from the main food groups and should drink plenty of fluids each day; in addition, at least 30 minutes of physical activity is recommended on most days of the week (Ministry of Health, 2013a). It is recommended older people have at least one serving a day of iron-containing foods, such as lean meat, skinless chicken, seafood, eggs and legumes.

There is a growing area of New Zealand research to address the issue of the difficulty of chewing meat in older adults, and subsequent reduced energy intake.

TABLE 4: RECOMMENDED SERVING SIZES FOR MEAT AND ALTERNATIVES

Serving size for lean meat, chicken, seafood, eggs and legumes
2 slices (100g) cooked meat
¾ cup (195g) mince or casserole
1 egg (50g)
1 medium fillet of cooked fish (100g)
1 medium steak (120g)
¾ cup (135g) cooked dried beans
2 drumsticks or 1 chicken leg (110g)

Source: Ministry of Health, 2003

6. EATING PATTERNS OF NEW ZEALANDERS

Two significant national nutrition surveys carried out in New Zealand provide a comprehensive picture of New Zealanders' eating patterns. The 2008/09 New Zealand Adult Nutrition Survey: A Focus on Nutrition (University of Otago & Ministry of Health, 2011), studied New Zealanders aged 15 years and older. This survey updates the 1997 survey NZ Food: NZ People (Russell et al., 1999). The 2002 survey, NZ Food NZ Children (Parnell et al., 2003) looked at New Zealand children aged 5 to 14 years.

In the Adult Nutrition Survey (2008/09), most of the population (94.5%) reported eating red meat in the previous four weeks, with red meat eaten 1-2 times per week by 30.1% and 3-4 times per week by 45.4%. More than half the population trimmed the excess fat from meat regularly or always (University of Otago & Ministry of Health, 2011).

Among children, 95% consume an omnivorous diet, with just 3.6% avoiding red meat and 0.7% avoiding all meat (Parnell et al., 2003). Meat makes a valuable contribution to the intake of a range of nutrients for many New Zealanders (see section 3).

7. ARE CURRENT RECOMMENDATIONS FOR MEAT INTAKE ADEQUATE?

Overall, the Ministry of Health's food and nutrition guidelines suggest 1-2 portions per day should be eaten from the meat and alternatives food group. However, in order to optimise health and prevent chronic disease, recommendations on the number of servings consumed from the meat and alternatives food group may need to be reviewed. Dietary modelling in Australia (NHMRC 2011) demonstrated the most limiting nutrient of the 10 nutrients modelled in the low energy Omnivore Foundation Diets was iron. The dietary models developed were unable to provide sufficient iron to fulfil the estimated requirements of pregnant females as a group.

Legumes, nuts and seeds certainly provide valuable nutrients and should be included in a balanced diet, but these foods are not direct substitutes for foods of animal origin in terms of the nutrients they provide. The recommended number of servings from the meat and alternatives group, along with the serving sizes, may need to be reconsidered and recommendations in relation to legumes, nuts and seeds as alternatives to meat may need to be revised.

Specific and separate advice and recommendations may be needed for lacto-vegetarians and vegans to ensure their nutritional requirements are met. However, the total combination of foods consumed over time is a more important consideration than the intake of individual foods, so further research and analysis of this issue is warranted before firm recommendations can be made.

8. THE ROLE OF RED MEAT IN HEALTH AND DISEASE

Meat consumption has been linked to a number of diseases, most notably cancer and heart disease. Research on heart disease and cancer is reviewed in sections 8.1.1 and 8.1.2.

Research evaluating the role of high-protein diets in promoting satiety and aiding weight loss is reviewed in section 8.3. Red meat is an excellent source of protein (see section 3.2) and makes a valuable contribution to protein intakes (along with other protein foods). This may be helpful for those managing their weight. The effects of a diet high in protein have also been evaluated in those with Type 2 diabetes and insulin resistance, with initial results showing such diets may be helpful (see section 8.4).

Emerging research suggests red meat may also play a role supporting optimal mental health. Specific analysis of red meat in relation to mood and anxiety disorders among women has shown that those consuming less than the recommended intake of red meat are at increased risk of depression, although more research is needed in this area to confirm which dietary strategies support optimal mental health (see section 8.5).

The role of meat in health and disease has been evaluated in a number of studies, which are outlined below.

8.1 CORONARY HEART DISEASE (CHD)

8.1.1. DIETARY FATS AND CORONARY HEART DISEASE

A Cochrane review on modifying dietary fat intakes for preventing cardiovascular disease concluded that replacing saturated fats with plant oils and unsaturated spreads may reduce the risk of heart and vascular disease, although it was not clear whether monounsaturated or polyunsaturated fats are more beneficial (Hooper et al., 2012).

More recent research has questioned whether a higher consumption of polyunsaturated fats and a lower consumption of saturated fats should be encouraged, and suggests this approach is not supported by recent evidence (Chowdhury et al., 2014; Schwingshackl & Hoffmann, 2014; Calder, 2013; Ramsden et al., 2013; Ravnskov et al., 2014; Thornley et al., 2014). However, the meta-analysis of dietary fatty acids and risk of coronary heart disease by Chowdhury et al. (2014), which reports no significant association between CHD outcomes and intakes of SFA, MUFA and both *n*-3 PUFA and *n*-6 PUFA, has been highly criticised. Experts claim it contains multiple errors and omissions, and the conclusions are seriously misleading (Willett et al., 2014).

There have been a number of systematic reviews that have supported a reduction in intake of saturated fats; for example a pooled analysis of 11 prospective cohort studies by Jakobsen et al in 2009 found that substituting 5% of energy from saturated fats with 5% of energy from polyunsaturated fats was associated with a significant reduction in CHD events. MUFA was not associated with CHD in this review. A further review by Mozaffarian et al in 2010, which was a meta-analysis of 8 randomised controlled trials, also found that replacing saturated fats with polyunsaturated fats reduced CHD events. Further, a recent New Zealand review of the highest quality systematic reviews suggests that replacing 5% of daily energy consumed as saturated fat with polyunsaturated fats would reduce ischaemic heart disease events by about 10% and that such a dietary change would be desirable and feasible for the New Zealand population (Foster & Wilson, 2013). There are no benefits in replacing saturated fats with refined starches, especially sugar (Hooper et al., 2012; Lawrence, 2013; Te Morenga et al., 2014a, Te Morenga et al., 2014b).

Experts in New Zealand have recently reviewed the available literature and conclude that numerous high quality experimental trials have provided unequivocal evidence that dietary saturated fat raises serum cholesterol levels when compared with polyunsaturated and monounsaturated fats (Te Morenga et al., 2014a).

The New Zealand Heart Foundation recommends replacing foods high in saturated fat with unsaturated fats (Gorton, 2014). The Heart Foundation advises that a diet of mostly minimally processed foods (including plenty of vegetables and fruit; plus legumes, nuts, whole grains, plant oils, fish, lean meats and reduced-fat dairy) is the best way of eating for a healthy heart. Dietitians New Zealand considers there not to be any substantive evidence that saturated fat is good for you in the long term (Dietitians New Zealand, 2014). It has been suggested that saturated fats be replaced with more *n*-3 polyunsaturated fatty acids. (Te Morenga et al., 2014a).

It is appropriate to regularly review nutrition recommendations in the light of new evidence; however, the best quality evidence at the present time supports current advice to reduce intake of SFA (Te Morenga et al., 2014b).

8.1.2. MEAT AND CORONARY HEART DISEASE

Health messages specifically in relation to meat can be confusing and misleading (Li et al., 2005) and advice to reduce red meat as part of a heart-healthy diet is inappropriate. A number of studies have shown lean red meat can be included in a heart-healthy diet as it is low in total fat and saturated fatty acids.

8.1.2.1. THE ROLE OF LEAN MEAT IN CHOLESTEROL-LOWERING DIETS

A study aiming to differentiate between lean beef and beef fat as risk factors for elevated plasma cholesterol, found total cholesterol concentrations fell significantly within one week of commencing a low-fat diet that included lean beef, and rose as beef dripping was added in a stepwise manner (O'Dea et al., 1990). This demonstrates clearly it is the beef fat and not the lean beef that is associated with elevations in cholesterol levels and shows lean beef can be part of a cholesterol-lowering diet. A further study, which looked at dietary determinants of ischaemic heart disease (IHD) in health conscious individuals, concluded that dietary saturated animal fat and cholesterol are important in the aetiology of IHD (Mann et al., 1997a). These factors, rather than simply meat, appeared to explain the higher IHD rates reported in meat eaters compared with vegetarians.

Substituting poultry for lean red meat is unlikely to have any effect on total or LDL cholesterol levels. A randomised controlled trial among hypercholesterolaemic free-living men and women comparing lean red meat with lean white meat found both produced similar reductions in LDL cholesterol and elevations in HDL cholesterol (Davidson et al., 1999). A further randomised cross-over study, with two 36-week phases separated by a 4-week washout period, compared the effects of lean red meat and poultry in reducing cholesterol in people with hypercholesterolaemia (Hunninghake et al., 2000). Results showed both had an identical effect, with a 1% reduction in total cholesterol and a 2% reduction in LDL cholesterol. In this study, the lean meat was part of a diet providing less than 30% energy from fat and 8-10% energy from saturated fatty acids.

A further study on hypercholesterolaemic men (Beauchesne-Rondeau et al., 2003) found diets containing lean beef or poultry reduced plasma total and LDL cholesterol concentrations by 8% each, with a 5% reduction in the lean fish-containing diet.

Analysis of the diets of adolescent girls also suggests lean red meat may be included in a healthy diet without unfavourable effects on lipid profiles (Bradlee et al., 2013). Another meta-analysis found that changes in the fasting lipid profile were not significantly different with beef consumption compared with poultry and/or fish consumption (Maki et al., 2012). Including lean beef in the diet increases the variety of food choice and may improve the long-term adherence with dietary recommendations for lipid management, say the authors of this study.

It has been suggested iron can contribute to oxidative stress and inflammation, which are possible risk factors for heart disease and diabetes. One study investigated the effects of lean red meat on markers of oxidative stress and inflammation in humans (Hodgson et al., 2007). Sixty subjects were randomised to either maintain their usual diet, or to partly replace energy from carbohydrate with 200g of lean red meat daily. No elevation of oxidative stress or inflammation was found among the meat-eating group.

A review of 54 studies that looked at meat consumption and CHD risk factors, found substantial evidence that lean meat trimmed of visible fat does not raise blood cholesterol and LDL cholesterol levels (Li et al., 2005), as long as the overall diet is low in total and saturated fat. In fact, the overall effect was diets low in saturated fatty acids, which included lean red meat, were associated with a reduction of LDL cholesterol levels in both hypercholesterolaemic and healthy subjects. Thrombotic risk factors such as thromboxane and prostacyclin production, platelet function and haemostatic factors also remain unchanged with the inclusion of lean red meat (Mann et al., 1997b).

Where lean meat is eaten, there appears to be little difference between meat-eaters and vegetarians in terms of blood lipid levels, as long as the overall diet is low in fat and saturated fatty acids. The Heart Foundation states small or moderate servings of lean meat can be included as part of a normal, varied diet (National Heart Foundation, 1999).

8.1.2.2. ADVICE ON MEAT IN RELATION TO CHD

The New Zealand Guidelines Group (2012) for cardiovascular risk factor management recommends including fish or dried peas, beans and soy products, or a small serving of lean meat or skinned poultry, at one or two meals each day. A serving of meat is 2 slices (100-120g) or half a cup of minced meat (125g). Intake of fatty meat and meat products (eg meat pies, sausage rolls, tinned corned beef and salamis) should be low, and all visible fat should be trimmed from meat before consumption (National Heart Foundation, 1999).

8.2. CANCER

8.2.1. INCIDENCE OF COLORECTAL CANCER IN NEW ZEALAND

In 2008, 2,801 people were diagnosed with bowel cancer and 1,280 people died from the disease. Colorectal cancer was the second most common cause of death from cancer in New Zealand, accounting for 15% of all deaths from cancer (Ministry of Health, 2011).

8.2.2. RED MEAT AND COLORECTAL CANCER

Some scientific studies have suggested a link between red meat consumption and colorectal cancer and the World Cancer Research Fund report (WCRF, 2007) and the 2011 Continuous Update Project (CUP) report on Colorectal Cancer concluded red and processed meats are a convincing cause of colorectal cancer based on a substantial amount of data from cohort studies showing a dose-response relationship. However, this remains controversial and the subject of scientific debate. Diet is remarkably difficult to measure, and the separation of the effects of individual food components is extremely complicated, given the multiple correlations that exist between the different elements (Boyle et al., 2008). The recommendation from the World Cancer Research Fund is to consume up to 500g cooked red meat per week with the average beef and lamb intakes in New Zealand currently sit below this level at around 400g/week. The 2011 CUP report on colorectal cancer confirms the evidence for a protective effect from foods containing dietary fibre has strengthened since the 2007 WCRF report.

Some meta-analyses have found that a high intake of red and processed meat is associated with an increased risk of colorectal cancer. (Sandhu et al., 2001; Norat et al., 2002; Larsson et al., 2006; Chan et al., 2011).

The meta-analysis by Sandhu et al. (2001), found a daily increase of 100g of all meat or red meat was associated with a significant 12-17% increased risk of colorectal cancer. A significant 49% increased risk was found for a daily increase of 25g of processed meat. However, as only a few of the studies reviewed attempted to examine the independent effect of meat intake on colorectal cancer risk, the overall association may have been confounded by other factors.

A further meta-analysis by Norat et al. in 2002 also found a high intake of red meat, and particularly processed meat, was associated with a moderate but significant increase in colorectal cancer risk. Average relative risks and 95% confidence intervals (CI) for the highest quantile of red meat consumption were 1.35 (CI: 1.21-1.51) and for processed meat were 1.31 (CI: 1.13-1.51). No significant association was found for total meat consumption and colorectal cancer risk. The relative risks for total and red meat were higher in studies including processed meat in the definition of these two meat groups, than in studies that evaluated fresh meat and fresh red meat.

Similar results were found in a meta-analysis in 2006 by Larsson et al., which found consumption of red meat and processed meat was positively associated with risk of both colon and rectal cancer.

The summary relative risks of colorectal cancer for the highest versus the lowest intake categories were 1.28 (95% CI: 1.15-1.42) for red meat and 1.20 (95% CI: 1.11-1.31) for processed meat.

A more recent meta-analysis (Chan et al., 2011) found the summary relative risk of colorectal cancer for the highest versus the lowest intakes of meat was 1.22 (95% CI = 1.11-1.34). Relative risk for every 100g/day increase was 1.14 (95% CI = 1.04-1.24). The mean values of the highest category of red and processed meat intake in the studies ranged from 46g to 211g per day. The authors conclude that overall evidence supports limiting red and processed meat consumption as one of the dietary recommendations for the prevention of colorectal cancer.

One of the largest studies of diet and health ever undertaken is the European Prospective Investigation into Cancer (EPIC). Results from this study, based on 478,040 men and women, support the hypothesis that colorectal cancer risk is positively associated with intake of red and processed meat (highest intake was over 160g per day, versus the lowest intake which was less than 20g per day) (Norat et al., 2005). The association with colorectal cancer was stronger for processed than for unprocessed red meat.

An expert workshop held in New Zealand in 1999, concluded there is no convincing evidence from published epidemiological studies that moderate intakes of lean red meat increase the risk of colorectal cancer when eaten as part of a mixed diet including carbohydrates, vegetables and fruits, and dairy products (Tasman-Jones, 2000).

More recent meta-analyses have shown that associations between red meat consumption and colorectal cancer are generally weak in magnitude, with most relative risks being below 1.5 and not statistically significant, there is also a lack of a clear dose response trend (Alexander & Cushing, 2010; Alexander et al., 2011).

8.2.3. POSSIBLE MECHANISMS LINKING MEAT CONSUMPTION WITH COLORECTAL CANCER

There are a number of possible mechanisms for a link between meat consumption and colorectal cancer; including the promotion of carcinogenesis by high-fat diets, the production of carcinogenic heterocyclic amines (HCAs) and polycyclic aromatic hydrocarbons (PAHs), the promotion of carcinogenesis by haem iron, and the formation of carcinogenic N-nitroso compounds (NOCs) both within meat and endogenously (WCRF, 2007; Baghurst, 2007; Santarelli et al., 2008).

Although fat intake from meat has been suggested to explain a link between colorectal cancer and meat intake, experimental studies show inconsistent results and epidemiological studies have failed to confirm a link (Santarelli et al., 2008). There is now little support for the notion that fat in meat promotes carcinogenesis (Baghurst, 2007). The 2011 WCRF Continuous Update Project (CUP) reports the evidence suggesting that consumption of foods containing animals fats is a cause of colorectal cancer is limited.

HCAs are produced during high-temperature cooking of meat, such as frying and when using a barbecue. Such high cooking temperatures cause amino acids and creatine to react together to form HCAs (WCRF, 2007). PAHs are produced from the incomplete combustion of organic compounds; the main sources are cooked and smoked meat and fish (notably barbecued meat) and tobacco smoke (Santarelli et al., 2008). Around one third of meat consumed on a daily basis in New Zealand is cooked by methods likely to result in the formation of HCAs (Thomson, 1999). However, a recent review of HCAs concluded there is not sufficient scientific evidence to support the hypothesis that human cancer risk is specifically due to the intake of HCAs in the diet (Alaejos et al., 2008). Data on PAHs in overcooked meat suggest these may be a risk factor, but there is insufficient evidence to draw firm conclusions (Santarelli et al., 2008). A more recent Australian population-based case-control study asked subjects to complete questionnaires on lifestyle and meat consumption (Tabatebaei et al., 2011). Baked red meat had a statistically significant inverse trend of association with colorectal cancer. Overall, results did not support an association between meat consumption or meat cooking practices, and the risk of colorectal cancer.

Haem iron may catalyse the formation of NOCs from natural precursors in the gut. Red meats are a richer source of haem iron than white meats, so such an effect may theoretically explain a stronger association between red meat and colorectal cancer, than between white meat and colorectal cancer. It would not explain, however, why white meat and fish (which also contain haem iron) appear to be protective against colorectal cancer (Baghurst, 2007). The 2011 CUP panel agreed the evidence suggesting foods containing iron to be a cause of colorectal cancer to be limited.

NOCs are alkylating agents that can react with DNA and are produced by the reaction of nitrite and nitrogen oxides with secondary amines and N-alkylamides (Santarelli et al., 2008). NOCs are present in certain processed meats (eg grilled bacon), smoked fish, cheeses and beer, and can be formed endogenously after red and processed meat consumption (Santarelli et al., 2008). Although some research has linked NOCs to cancer, it is not yet clear whether red and processed meat-induced NOCs are colon carcinogens (Santarelli et al., 2008). Further research is needed in this area.

8.2.4. REDUCING RISK OF COLORECTAL CANCER (CRC)

Epidemiological and mechanistic data on associations between red meat and colorectal cancer are inconsistent, and underlying mechanisms are unclear; there is a need for further research into the differences between white meat, red meat and processed meat, and there is a need for further investigation of biomarkers of meat intake and cancer occurrence (Oostindjer et al., 2014).

There are many dietary and lifestyle factors that have an influence on the development of cancer. In many studies looking at the effects of diet on cancer, it is difficult to disentangle the dietary and lifestyle factors that may be involved (such as Western lifestyles, high intake of refined sugars, alcohol, low intakes of fruits, vegetables and fibre) and behavioural factors (such as smoking, lack of physical activity and high body mass index). This limits the ability to analytically isolate the independent effects of red meat consumption; currently available epidemiological evidence is not sufficient to support an independent positive association between red meat consumption and colorectal cancer (Alexander & Cushing, 2011).

The key focus in terms of cancer prevention should be to: avoid smoking, limit sun exposure, maintain a healthy body weight and be physically active as part of everyday life. In terms of diet, it is recommended we eat at least five portions of a variety of fruits and vegetables each day, along with relatively unprocessed cereals and pulses, and limit intake of alcohol to no more than 1 unit a day for women and 2 units a day for men (WCRF, 2007). The 2011 CUP colorectal report confirms the evidence for ethanol from alcoholic drinks being a cause of colorectal cancer in men is convincing and probable in women. In addition, the CUP panel agree the evidence showing physical activity to protect against colon cancer is convincing, and greater body and abdominal fatness as a CRC cause to be convincing.

Lean beef and lamb can make an important nutritional contribution to a balanced diet and complete avoidance is unnecessary in terms of cancer prevention. Also of note is that some of the nutrients in red meat, such as selenium, and vitamins B_6, B_{12} and D, may have anti-cancer properties. Adjusting the dietary balance between meat and other dietary components may be critical in protecting against potential cancer (Ferguson, 2009). The 2011 CUP CRC report confirms evidence for foods containing vitamin D and/or selenium to be protective, is limited.

As research in this area continues, it may be prudent to avoid very high intakes, particularly of processed meats, and to limit very high temperature cooking methods. The WCRF (2007) have recommended that intakes of cooked red meat can be up to 500g per week. Twenty-four hour recall data from the New Zealand adult national nutrition survey shows a daily serving of 179.6g of beef and veal, and 137.2g lamb and mutton, which reflects an average portion size. At a population level, New Zealanders are eating an average 41.1g/day of beef and veal, and 9.3g/day of lamb and mutton (Parnell et al, 2012).

8.3. OBESITY

Conservative estimates suggest over 1 billion people worldwide are overweight or obese (Simpson & Raubenheimer, 2005). Obesity is certainly a significant problem in New Zealand, three out of ten adults (31%) are now obese, and one in nine (11%) of children aged 2-14 years are obese. This means that 1.2 million New Zealanders are obese (Ministry of Health 2013b).

8.3.1 PROTEIN AND WEIGHT MANAGEMENT

Evidence is accumulating that increasing intakes of high-quality protein to a level above the recommended intake may be beneficial during weight loss (Layman, 2004), as well as for diabetes and cardiovascular disease (Rodriguez & Garlik, 2008). This may be related to the positive effects of protein on appetite control, satiety

and food craving and reduction of intake of fat and carbohydrate (Santesso et al, 2013).

Astrup et al. 2013 looked at the effect of protein-induced satiety on appetite hormones which concluded protein dose-dependency increased satiety and postprandial changes in circulating GLP-1, PYY and glycagon were in part, responsible for the appetite suppressant effect of protein.

Energy intake has been shown to increase as dietary protein falls from 20% to 10%; a recent review on protein leverage and energy intake concludes that dilution of protein in the diet stimulates excess energy intakes, and that there is strong support for a role of protein leverage in lean, overweight and obese humans Gosby et al., 2014).

For most of our existence, the human diet has consisted of a high proportion of animal foods, with meat consumed from wild animals typically having a low fat content (see section 2). As a result, we have limited evolutionary experience of excess carbohydrates or fats and it has been suggested natural selection against over-consumption of these nutrients would not have been strong; this may account for their high level of palatability and may predispose us to their over-consumption today (Simpson & Raubenheimer, 2005).

In terms of systematic reviews and meta-analyses, 15 randomised controlled trials looked at the long term effects of higher vs lower protein diets on health outcomes including adiposity (Schwingshackl & Hoffman, 2013). Data analysis revealed no significant changes for weight, waist circumference, fat mass, total cholesterol and blood pressure. Significant decreases for fasting insulin were observed in high-protein diets compared to low-protein diets in the primary analysis, but not so in the secondary analysis. It summarised high-protein diets exerted neither specific beneficial or detrimental effects on outcome markers of obesity, cardiovascular disease or glycaemic control.

In a large European study (Larson et al., 2010), 773 participants completed a low calorie phase, and were then randomly assigned to one of five weight maintenance diets; 548 completed the intervention. The mean initial weight loss on the low-calorie diet was 11.0kg; among those who completed the study, only those following the low-protein, high-glycaemic index diet significantly re-gained the weight. The authors conclude that a modest increase in protein (to 25% of energy), and a modest reduction in glycaemic index, led to an improvement in study completion and maintenance of weight loss.

More recently, the DIOGENES 12 month randomised clinical trial (Aller et al., 2014) looked at both the glycaemic index (GI) and protein content effect on overweight subjects who were put on an initial low calorie diet for 8 weeks. After the intervention, the trial found no consistent effect of GI on weight gain, but did show a diet higher in protein (23-28%) improved weight loss maintenance in overweight and obese adults.

More evidence for the effect of protein is provided by a meta-analysis of 87 studies comprising 165 intervention groups, which found low carbohydrate, high-protein diets affected body mass and composition favourably, independent of energy intake (Kreiger et al., 2006). This supports the proposed metabolic advantage of such diets.

A more recent systematic review and meta-analysis compared an energy restricted standard protein diet with an isocalorically prescribed high-protein diet and found a beneficial effect on weight loss, body composition and triglycerides with higher protein intakes (Wycherley et al., 2012).

Concern has been expressed about the effects of high-protein diets on renal function; however, there is little evidence high-protein diets pose a serious risk to kidney function in healthy people (Halton & Hu, 2004). Similarly, the impact of high-protein diets on markers of bone turnover has not been found to be deleterious (Noakes et al., 2005; Farnsworth et al., 2003).

Many of the studies on protein and weight loss have been relatively small. Optimal amounts and sources of protein cannot be determined, but the weight of evidence suggests it may be beneficial to partly replace refined carbohydrate intake with low-fat protein sources (Halton & Hu, 2004).

8.3.2. FAT AND CARBOHYDRATES AND WEIGHT MANAGEMENT

It is important to consider not only the protein content of the diet but also the fat and carbohydrate content. Research into low-carbohydrate versus low-fat diets is mixed. One study on 96 normoglycaemic insulin-resistant women randomised to one of three dietary interventions (high-carbohydrate, high-fibre; high-fat; or high-protein) for 8 weeks of supervised weight loss, and 8 weeks of supervised weight maintenance, found significantly greater reductions in weight on the high-fat and high-protein diets, when compared with the high-carbohydrate diets (McAuley et al., 2005). However, the authors suggest that to achieve similar benefits on a high-carbohydrate diet, it may be necessary to increase fibre-rich whole-grains, legumes, vegetables and fruits, and to reduce saturated fatty acids to a greater extent. Although the high-fat diet was successful for weight loss in the short term, the authors expressed concern that lipid levels should be monitored owing to the possible deleterious effects of this diet in the long-term.

A recent meta-analysis compared the effects of low-carbohydrate diets (< 45% energy from carbohydrates) versus low-fat diets (< 30% energy from fats) on metabolic risk factors and weight loss (Hu et al., 2012). Reductions in body weight, waist circumference and other metabolic risk factors were not statistically significant between the two diets.

When looking at high-carbohydrate diets it is important to consider carbohydrate quality, which is not addressed in many studies. Recent research has compared a high-protein diet (28% of energy from protein, of which 75% was derived from animal sources), with a low-fat high-carbohydrate diet (22% energy from protein) that was rich in dietary fibre from minimally processed grains, cereals and legumes (Te Morenga & Mann, 2012).

Each diet provided 24g/d and 39g/d of dietary fibre respectively.

After 8 weeks both groups lost weight, but the high-protein participants lost 1.3kg more weight and achieved a greater reduction in diastolic blood pressure. Although improvements in risk factors were most marked on the high-protein diet, results did not achieve statistical significance.

A recent position statement by the New Zealand Dietetic Association considers there not to be any evidence that a diet high in fat and low in carbohydrates is more beneficial for sustained weight loss than any other dietary regimen that results in a lower intake of energy (Dietitians New Zealand, 2014).

Further research in needed into the optimal dietary balance of fats and carbohydrates for long-term weight-loss. However, it seems reasonable to suggest that relatively higher protein intakes are an appropriate option for the treatment and avoidance of excess body fat (Te Morenga & Mann, 2012). For weight loss, the diet should be reduced in energy, and carbohydrate sources should be low in glycaemic index with minimally processed grains, cereals and legumes. The inclusion of lean red meat as part of a balanced diet would contribute to increased protein intakes.

8.4 TYPE 2 DIABETES

High-protein, low-carbohydrate diets have also been examined for treatment of Type 2 diabetes mellitus. Positive effects have been found on glycaemic regulation including: reductions in fasting blood glucose; reductions in post-prandial glucose; reductions in insulin responses; and a reduced percentage of glycated haemoglobin (Layman et al., 2008). More recently, it has been claimed that although low-carbohydrate diets are still controversial, they have continued to demonstrate effectiveness with little risk and good compliance for those with diabetes (Feinman et al., 2015).

A study comparing a high-protein diet (28% of energy) with a low-protein diet (16% of energy) in 54 obese men and women with Type 2 diabetes, during 8 weeks of energy restriction and 4 weeks of energy balance, found both diets improved the cardiovascular disease risk profile as a consequence of weight loss (Parker et al., 2002). However, there were greater reductions in total and abdominal fat mass in women, and greater LDL cholesterol reduction in both sexes, with the high-protein diet. This suggests high-protein diets are a valid choice for reduced risk of cardiovascular disease in people with Type 2 diabetes. Subjects in this study derived their protein from foods such as beef, chicken and dairy products.

A further study on overweight and obese hyperinsulinaemic men and women found no difference in weight loss or fat mass loss between subjects fed a high-protein diet (27% of energy) compared with a lower protein diet (16% of energy) during 12 weeks of energy restriction and 4 weeks of energy balance (Farnsworth et al., 2003). However, in women total lean mass was significantly better preserved with the high-protein diet (-0.1 + 0.3 kg) than with the standard protein diet (-1.5 + 0.3 kg).

Further, those on the high-protein diet had significantly less glycaemic response and a greater reduction in triacylglycerol concentrations than those on the standard protein diet.

Although there have been relatively few studies comparing the effects of high-protein diets varying in macronutrient composition on insulin sensitivity, limited data suggest that moderately high-protein, weight-loss diets (25-30% energy) improve glucose metabolism and insulin sensitivity when compared with low-fat, high-carbohydrate diets (Te Morenga & Mann, 2012).

Further studies are warranted into the effect of high-protein diets on delaying the progression to Type 2 diabetes in obese adults with insulin resistance. Initial indications are however, that for some individuals a diet providing an increased level of protein and a reduced level of carbohydrate may be effective for weight management, may improve lipid profiles, and may improve glycaemic regulation (Layman et al., 2008). However, it is important to note again the nature of the carbohydrates consumed in many studies was not considered (Te Morenga & Mann, 2012). More research is needed to determine the types and amounts of macronutrients to include in an optimal diet for people with diabetes.

8.5 MENTAL HEALTH

Mental health is an integral part of health and well-being, as reflected in the definition of health in the Constitution of the World Health Organisation: “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.” (WHO, 2013).

Depression alone accounts for 4.3% of the global burden of disease and is among the largest single causes of disability worldwide (WHO, 2013). In New Zealand, rates of diagnosed mental health conditions are on the rise with rates of psychological distress high among Māori and Pacific adults, and adults living in the most deprived areas (Ministry of Health, 2014).

Recent research suggests nutrition is a key factor that underpins depression, with healthy dietary practices associated with a reduced likelihood of both clinically diagnosed depressive and anxiety disorders, and unhealthy dietary habits associated with an increased likelihood of major depressive disorder, dysthymia and anxiety disorders (Jacka et al., 2010).

Healthy dietary patterns consisting of vegetables, salads, fruits, rice, pasta, cereals, wine and non-processed meats have been compared with ‘Western’ dietary patterns consisting of processed meats, pizza, salty snacks, chocolates, sugar, sweets, soft drinks, margarine, mayonnaise, French fries, beer, coffee, cake and ice-cream. Those on better quality diets have been shown to be less likely to be depressed whereas a higher intake of unhealthy and processed foods has been associated with an increased level of anxiety (Jacka et al., 2011a). The hypothesis of reverse causality is not supported by the available data, in other words, the reported associations do not reflect poorer eating habits as a consequence of mental health problems (Jacka et al., 2011b).

Specific analysis among women eating red meat in relation to mood and anxiety disorders, has shown for those women consuming less than the recommended intake of red meat per week (3-4 serves of 65-100g a week of red meat such as beef and lamb), the odds for major depressive disorder/dysthymia were more than doubled compared to those consuming the recommended intakes (Jacka et al., 2012). The authors conclude that red meat consumption may play a role in mental health independently of overall dietary quality, but further studies are needed before recommendations can be made.

It is likely it is overall dietary patterns that are protective, rather than a single food component. It has been suggested, for example, the synergistic combination of *n*-3 fatty acids together with other unsaturated fatty acids and antioxidants from olive oil and nuts, flavanoids and other phytochemicals from fruit and other plant foods, and large amounts of natural folates and other B vitamins, exert a fair degree of protection against depression (Sánchez-Villegas et al., 2009).

A randomised controlled trial is currently underway to investigate the efficacy of dietary improvements in the treatment of depression (O'Neil et al., 2013). If the results of this study are positive, dietary intervention could provide an alternative or adjunctive treatment strategy for the management of mental disorders. In the meantime, it makes sense to follow a healthy diet for optimal physical and mental well-being.

CONCLUSION

Meat has been an important part of the human diet throughout our evolutionary history and today most New Zealanders include meat in their diet. Lean New Zealand beef and lamb are nutrient-dense foods that play a pivotal role throughout the life cycle – from young infants and children, through to adults and older people.

In particular, red meat is a rich source of bioavailable iron, which is important for vulnerable groups such as infants and toddlers, adolescents and women of childbearing age. Meat also provides zinc, selenium, B vitamins (particularly vitamin B_{12}), vitamin D and *n*-3 fatty acids, and liver is an excellent source of vitamin A. Red meat is also an excellent source of protein, and when fully trimmed, is low in total and saturated fatty acids.

The combination of nutrients found in meat can play an important role in the health issues facing many New Zealanders today. For example, lean meat can be a helpful part of a heart-healthy diet for those at risk of cardiovascular disease; it can form a part of a weight-reducing diet for obese and overweight people; and may have beneficial effects in preventing and managing Type 2 diabetes.

In terms of cancer prevention, the key focus should be to avoid smoking, limit sun exposure, maintain a healthy weight, and be physically active. In relation to diet, the emphasis should be on fruits, vegetables and unprocessed cereals and pulses, as well as limiting alcohol intake. A reduction in red meat intake in New Zealand is unnecessary based on current scientific evidence. However, it may be prudent to avoid very high intakes, particularly of processed meats, and to limit very high temperature cooking methods.

APPENDIX 1: COMMON MYTHS AND MISCONCEPTIONS ABOUT MEAT

RED MEAT IS HIGH IN FAT

When trimmed of all visible fat, lean red meat is low in fat. For example, a 100g portion of cooked beef silverside contains 5g fat and within that, only around half the fat in meat is saturated; the rest is mainly beneficial monounsaturated and polyunsaturated fats. Since 1997, the red meat industry's New Zealand Beef and Lamb Quality Mark has required the trimming of beef and lamb cuts to be no more than 5mm of external fat and resulted in 30% less total fat and 65% less saturated fat in beef and lamb cuts.

PEOPLE WITH HEART DISEASE SHOULD AVOID RED MEAT

A number of studies have shown lean red meat can be included in a cholesterol-lowering diet. Intake of fatty meat and meat products should be low for people with heart disease and all visible fat should be trimmed from meat before consumption. The New Zealand Guidelines Group (2012) for cardiovascular risk factor management recommends including fish or dried peas, beans and soy products, or a small serving of lean meat or skinned poultry, at one or two meals each day.

WEIGHT-LOSS DIETS SHOULD EXCLUDE RED MEAT

Lean red meat is low in fat and calories, and moderate amounts can be included in a weight-reducing diet. Evidence is accumulating that increasing the intake of high-quality protein to a level above the recommended daily amount (RDA), may be beneficial during weight loss; protein has been found to suppress food intake as it contributes to satiety, promoting a feeling of fullness. The inclusion of lean red meat as part of a balanced diet may therefore help weight loss as part of a reduced energy diet.

RED MEAT CAUSES CANCER

Some scientific studies have suggested an association between red meat consumption and colorectal cancer. However, associations are weak and overall evidence is mixed. An expert workshop in New Zealand concluded a moderate intake of lean meat as part of a balanced diet, which also provides adequate cereals and grain foods, vegetables and fruit, is not associated with an increased risk of bowel cancer. There are many dietary and lifestyle factors that influence the development of cancer and the key focus in terms of cancer prevention should be to avoid smoking, limit sun exposure, maintain a healthy body weight, be physically active, eat at least five portions of a variety of fruits and vegetables each day, along with unprocessed cereals and pulses, and limit intake of alcohol. The World Cancer Research Fund recommendation is that people who eat red meat (defined as beef, lamb and pork) should consume less than 500g cooked red meat per week. Current average red meat intakes in New Zealand are below this amount.

MEAT-EATERS SHOULD BECOME VEGETARIAN IF THEY WANT TO BE HEALTHY

A diet excluding meat can be nutritionally adequate, but as more foods are excluded it becomes important to plan the diet carefully to ensure nutrient needs are met. In particular, intakes of iron, zinc and vitamin B_{12} need careful consideration – especially for vegans.

In terms of chronic disease, vegetarians have a lower mortality rate than omnivores, although it is likely much of this effect can be achieved by not smoking, by exercising more and by consuming a diet higher in fruits, vegetables and fibre. It is difficult to disentangle which features of a vegetarian diet may be protective, and there is currently no evidence to suggest meat eaters should change to an entirely vegetarian diet for health reasons.

SPINACH IS THE BEST SOURCE OF DIETARY IRON

Spinach is a good source of iron, but the iron is present in the non-haem form, which is poorly absorbed, therefore should be eaten with vitamin C-rich foods such as tomato or capsicum. Also, spinach contains substances that inhibit the absorption of iron, such as polyphenols and oxalic acid. As a result, spinach is a relatively poor source of iron, especially when compared with red meat, which contains the more readily-absorbed haem iron.

EATING TOO MUCH MEAT CAN LEAD TO AN EXCESS IRON INTAKE

Absorption of iron from dietary sources is well controlled by the body and although red meat is an excellent source of iron, including it regularly in the diet will not lead to an excess iron intake for healthy people. In fact, iron deficiency is much more likely to be a problem. The most common iron overload condition in New Zealand is hereditary haemochromatosis, a genetic condition that causes poor control of iron absorption. This condition is managed by therapeutic phlebotomy - in other words, the removal of blood on a regular basis, not by the avoidance of meat.

MEAT TAKES A LONG TIME TO DIGEST

From an evolutionary perspective, humans are naturally omnivores and our digestive system is well adapted to digesting meat. Around 94% of the protein in meat is digested; this compares with 86% in whole wheat and 78% in beans (Williams, 2007). Meat takes approximately 2-4 hours to leave the stomach and is therefore an easily digested food. In addition, the nutrients in meat are well absorbed and utilised by the body.

APPENDIX 2: PRODUCTION OF RED MEAT IN NEW ZEALAND FARMING PRACTICES

The unique climate and landscape in New Zealand has set the global benchmark for pastoral farm production. Most meat is produced using naturally available resources – grass, rain and sunshine. In New Zealand, there is year-round access to grass, including hay, silage and feed crops.

SUSTAINABILITY

Researchers in the USA have suggested a meat-based diet requires more energy, land and water resources than a lacto-ovo-vegetarian diet (Pimentel & Pimentel, 2003) implying the lacto-ovo-vegetarian diet is more sustainable. However, these suggestions often assume land used for grazing animals can be diverted to other uses, such as crop production (Thomason, 2007). Furthermore, these studies are likely to have made the comparison with feedlot beef, rather than extensive pastoral systems. In New Zealand, most livestock production takes place on land unsuitable for producing crops, and if this land were not used for grazing, it would essentially be agriculturally unproductive.

Water foot-printing of New Zealand beef and lamb production shows the majority of water used is from natural rainfall, rather than from other sources of water, and often not reflected in sustainability comparisons.

As such, beef and lamb production in New Zealand is highly sustainable.

GREENHOUSE EMISSIONS

A recent report has shown greenhouse gases, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide, have continued to climb during 2013, once again reaching historic high values. Atmospheric CO_2 concentrations increased by 2.8ppm in 2013, reaching a global average of 395.3ppm for the year (Blunden & Arndt, 2014). Globally, livestock contributes a significant share towards emissions, but can also deliver a significant share of the necessary mitigation efforts (Gerber et al., 2013).

New Zealand is a signatory to the Kyoto Treaty on climate change and has made a commitment to reduce greenhouse emissions to 1990 levels. To help achieve this aim, the Pastoral Greenhouse Gas Research Consortium (PGgRc) was set up in 2002. A key goal of the PGgRc is to develop strategies to reduce and mitigate the two greenhouse gases associated with livestock: methane and nitrous oxide.

The contribution of agriculture to New Zealand's emissions profile is currently 46.1%, down from 50% in 1990. Emission levels from the beef and sheep sector have been decreasing and are now 17% lower than in 1990. Over the same period, emissions from agriculture have been increasing, therefore the sheep and beef sectors' contribution as a proportion is lower than it was 15 years ago. Breeding programmes along with the production of fewer, but larger animals are largely responsible for the increase in efficiency in this sector to date.

Looking to the future, a recent report by PGgRc outlines 5 objectives which will build on knowledge and research tools developed by PGgRc over the last 10 years. These objectives are to: breed low-CH_4 emitting ruminants; identify low-greenhouse-gas feeds, develop a vaccine to reduce ruminant CH_4 emissions, identify inhibitors that reduce ruminant CH_4 emissions and to extend and enable technologies that can be readily adopted by farmers (Aspin et al., 2014).

OTHER ENVIRONMENTAL ISSUES

The foundation of the New Zealand farming industry is fertile land, clean water and fresh air and a number of programmes are in place in New Zealand aimed at supporting environmental sustainability.

A significant environmental challenge is maintaining soil fertility while limiting nutrient loss to waterways. A recent high-profile project, funded by industry, farmers and government was 'The Wise Use of Nitrogen Fertiliser' project. This was a 4 year project aimed at promoting the sound use of nitrogen fertilisers in a range of hill farming situations, in order to encourage practices that enhance long-term profitability while minimising any detrimental effects to the environment.

The National Policy Statement for Freshwater Management (2011) requires communities to establish objectives that maintain or improve the quality of all freshwater in a region, with a planning framework to manage resources to achieve to the objectives. National bottom lines have been set for key water quality objectives.

The New Zealand economy is dependent on the environment to support activities such as agriculture. To sustain the environment, a range of policy initiatives are currently being implemented in the beef and sheep sector to ensure the industry remains economically profitable and environmentally sustainable in future years.

ANTIBIOTICS

In New Zealand, antibiotics are used sparingly in animals for therapeutic reasons only. Any treatment with antibiotics is recorded and statutory declarations are made. Animals treated with antibiotics are required to be withheld from the market for a specified period of time.

HORMONAL GROWTH PROMOTANTS

Hormonal growth promotants are only used in a very small number of livestock (less than 1%) and are only provided under veterinary supervision. Their use in New Zealand is very tightly controlled and any animals which have received such hormones must be tagged and included in a central government database.

There is no evidence of any adverse effect on human health through consumption of meat produced from animals given hormonal growth promotants. Any beef or lamb products displaying the Quality Mark have come from animals not treated with hormonal growth promotants.

RISK MANAGEMENT

The Animal Products Act 1999 (APA) is legislation that requires all animal products traded and used in New Zealand be fit for intended purpose and this is achieved through risk management programmes, which involve identifying and managing hazards and other risks (NZFSA, 2010). Individual plants must operate a risk management programme that is independently audited by the Ministry for Primary Industries (MPI).

Risk management programmes must comply with the required industry standards. Plants may also operate ISO (International Organisation for Standardisation) standards that incorporate HACCP (Hazard Analysis and Critical Control Points).

If a plant is to supply the overseas market, then the appropriate standards for the destination country must be met. For example, meat exported to the USA must meet United States Department of Agriculture (USDA) market access standards, and meat being exported to the European Union must meet EU standards.

NEW ZEALAND BEEF AND LAMB QUALITY MARK

The New Zealand Beef and Lamb Quality Mark was introduced in 1997 to ensure consistent quality of New Zealand beef and lamb. The Quality Mark is a black, red and gold rosette and provides customer assurance that the highest standards have been met for leanness, tenderness, animal welfare and food safety.

Meat must be trimmed to a maximum of 5mm external fat along with the removal of internal fat where practical. Often cuts are trimmed completely and have no visible fat at all. To be eligible for the Quality Mark, mince must contain less than 10% fat.

A significant amount of New Zealand beef and lamb (ie cuts containing less than 4% saturated fat with a maximum 5mm fat trim) also qualifies for the Heart Foundation's Two Ticks, being recognised as core foods as part of a healthy diet.

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