2007

Nutritional composition of red meat

P. G. Williams
University of Wollongong, peterw@uow.edu.au

Publication Details

This article was originally published as: Williams, PG, Nutritional composition of red meat, Nutrition & Dietetics, 2007, 64(Suppl 4), S113-S119. The definitive version is available at www.blackwell-synergy.com. Nutrition & Dietetics is the official journal of the Dietitians Association of Australia.

Nutritional composition of red meat

Abstract
Lean red meats are: • An excellent source of high biological value protein, vitamin B12, niacin, vitamin B6, iron, zinc and phosphorus • A source of long-chain omega-3 polyunsaturated fats, riboflavin, pantothenic acid, selenium and possibly also vitamin D • Mostly low in fat and sodium • Sources of a range of endogenous antioxidants and other bioactive substances including taurine, carnitine, carnosine, ubiquinone, glutathione and creatine.

Keywords
red meat, nutrients, beef, lamb, mutton, veal

Publication Details
This article was originally published as: Williams, PG, Nutritional composition of red meat, Nutrition & Dietetics, 2007, 64(Suppl 4), S113-S119. The definitive version is available at www.blackwell-synergy.com. Nutrition & Dietetics is the official journal of the Dietitians Association of Australia. Copyright 2007 Blackwell Publishing.

The Nutritional Composition of Red Meat

Assoc Prof Peter Williams PhD FDAA
Smart Foods Centre, University of Wollongong

Key Points

Lean red meats are:

- An excellent source of high biological value protein, vitamin B12, niacin, vitamin B6, iron, zinc and phosphorus
- A source of long-chain omega-3 polyunsaturated fats, riboflavin, pantothenic acid, selenium and possibly also vitamin D
- Mostly low in fat and sodium
- Sources of a range of endogenous antioxidants and other bioactive substances including taurine, carnitine, carnosine, ubiquinone, glutathione and creatine.

1) What is meat?

The Food Standards Australia New Zealand (FSANZ) Food Standard Code defines meat as 'the whole or part of the carcass of any buffalo, camel, cattle, deer, goat, hare, pig, poultry, rabbit or sheep, slaughtered other than in a wild state, but does not include eggs, or foetuses' [1]. This definition does not include kangaroo meat, which is now widely available for purchase in Australia and would be considered by most Australians as meat.

Commonly people use 'meat' to refer only to meat flesh (skeletal muscle plus any attached connective tissue or fat), but the FSANZ definition also includes offal (ie, meat other than meat flesh, including brain, heart, kidney, liver, pancreas, spleen, thymus, tongue and tripe) although it excludes bone and bone marrow.

In Australia, the term 'red meat' is used by the meat industry to refer to meat from cattle, sheep and goat (ie beef, veal, lamb, mutton and goat meat). It does not include meat from pigs (eg, pork, bacon, ham) or kangaroo, nor less common game meats like buffalo and camel, although nutrient composition of some of these products is now becoming available [2]. Purchased red meat usually consists of both lean tissue (muscle) and fat tissue, which can be either distributed throughout the muscle as marbling (internal fat) or surrounding the muscle meat as selvage or external fat. In trimmed lean meat, it is usually the external fat only that is removed.

Processed meat means a product containing no less than 30% meat, that has undergone a method of preservation other than freezing, and includes manufactured meat and cured and/or dried meat flesh (eg, sausages, salami, canned meats).

2) Nutrient composition of red meat

Red meat contains high biological value protein and important micronutrients that are needed for good health throughout life. It also contains a range of fats, including essential omega-3 polyunsaturated fats. Recent analyses have shown that there has been a significant trend to leaner cuts of meat over the past two decades [3]. While the nutritional composition will vary somewhat according to breed, feeding regimen, season and meat cut, in general lean red meat has a low fat content, is moderate in cholesterol and rich in protein and many essential vitamins and minerals.

2.1 Nutrient composition of beef, veal, lamb and mutton

Table 1 presents the typical nutrient composition of samples of fat-trimmed Australian red meat, based on recent analyses of national retail samples [4-6] and compares this to the new Australian recommended dietary intakes [7]. While there are some differences between the four meats, in general lean red meat is a particularly good source of protein, niacin, vitamin B6, vitamin B12, phosphorus, zinc and iron, with 100g providing more than 25% RDI of these nutrients. It also provides more than 10% RDI of riboflavin, pantothenic acid, and selenium. Of the four meats, mutton is particularly nutrient dense, and the richest source of thiamin, vitamins B6 and B12, phosphorus, iron and copper.

Protein and amino acids

Raw red muscle meat contains around 20-25g protein/100g. Cooked red meat contains 28-36g/100g, because the water content decreases and nutrients become more concentrated during cooking. The protein is highly digestible, around 94% compared to the digestibility of 78% in beans and 86% in whole wheat [8]. Protein from meat provides all essential amino acids (lysine, threonine, methionine, phenylalanine, tryptophan, leucine, isoleucine, valine) and has no limiting amino acids. Protein Digestibility Corrected Amino Acid Score (PDCAAS) is a method of evaluating the protein quality, with a maximum possible score of 1.0. Animal meats like beef have a score of approximately 0.9, compared to values of 0.5-0.7 for most plant foods [9]. The amino acid glutamic acid/glutamine is present in meat in the highest amounts (16.5%), followed by arginine, alanine, and aspartic acid.

Fat

Table 2 shows examples of the amount of separable fat found on typical retail cuts of red meat available for sale in Australia [3, 10]. There is a wide variation in the amount of total separable fat between the different beef and lamb cuts, ranging from 37% in loin lamb chops to only 1% in veal steak.

The gross composition values show that there generally appears to be less separable fat in the untrimmed raw retail samples collected in 2002 compared to those reported from 1983-86 [11, 12]. For example, the percentage separable fat has declined from 18% to 12% in rump steak and from 10% to 6.6% in fillet steak. This trend to lower fat cuts has been due to three factors: selective breeding and feeding practices designed to increase the carcase lean to fat ratio; meat classification and marketing systems designed to favour leaner products; and modern butchery techniques such as seaming out whole muscles and trimming away intermuscular fat [13].

Most Australian consumers today prepare and consume their meat after trimming external fat, and the most recent nutritional analyses show that all trimmed lean red meats are relatively low in fat (<7%) and have moderate cholesterol content, with the exception of mince meats (Table 3). An important contributor to the leanness of muscle meat in Australian beef and lamb is that almost all animals are pasture (grass) fed for most of their lives, although some are given short periods of grain finishing before slaughter.

Fatty acids

Much of the discussion about the fat content of red meat focuses on the saturated fat content. However, the amount of saturated fat in Australian beef and lamb is actually less than the total amount of unsaturated fats on a per edible portion basis.

Table 4 shows the average fatty acid profiles of beef, veal, lamb and mutton compared to other white meats and fish. Saturated fatty acids comprise, on average, 40% of total fatty acids in the lean component and 48% in the fat component of red meat. In beef and veal, approximately half of the saturated fatty acid in both the lean and fat component of red meat is palmitic acid (16:0) and about a third is stearic acid (18:0). In lamb and mutton the proportions of these two fatty acids is more similar. There is little variation between cuts in the proportion of fatty acids.

Polyunsaturated fatty acids (PUFA) range from 11% to 29% of total fatty acids. Pasture fed beef is better source of omega-3 fats than grain feed beef, and this explains the better fatty acid ratio in Australian red meat compared to that in the US, where there is extensive grain feeding [14, 15]. Beef and lamb also have more omega-3 fatty acids than either chicken or pork, although fish is still a significantly better source than any of the red meats.

The recent revision of the recommended dietary intakes for Australians recommended a daily adequate intake of long-chain omega-3 fats (DHA, EPA and DPA) of 160mg for men and 90mg for women, with higher targets of 610mg and 430mg respectively to reduce the risk of long term chronic disease [7]. Since the levels of long chain PUFA found in Australian beef, veal and lamb muscle meat are greater than 30mg per serving (135g) of red meat, they are considered a source of long chain n-3 PUFA according to Australian food regulations (Food Standards Australia New Zealand 2004). Mutton muscle meat, which has more than 60mg EPA + DHA per serving of red meat, can be described as a good source of long chain n-3 polyunsaturated fats. Red meat is frequently consumed by Australians and makes the second greatest contribution to intake of long chain n-3 PUFA, after fish, in the Australian diet [16].

Trans fatty acids
Trans fatty acids are found in ruminant fat as a result of biohydrogenation by rumen bacteria. Trans fatty acids (18:1 trans) in raw muscle meat varies from as little as 22mg/100g in veal to 123mg in lamb, but is generally less than 3% of the total fatty acid content [17]. Levels in both raw and cooked muscle meat are higher in lamb and mutton than in beef and veal.

Choline
Choline is a precursor of a number of compounds including neurotransmitters and membrane phospholipids. Although choline can be made in the body, dietary essentiality has been demonstrated and the new Australian nutrient reference values recommend an adequate intake of 550mg/d for men and 425mg/d for women [7]. The best dietary sources are milk, liver and eggs, but meat is also a significant source and beef contains 78mg/100g [18].

Vitamins
As with other animal foods, red meat is an excellent source of bioavailable vitamin B12, providing over two thirds of the daily requirement in a 100g serve (Table 1). Up to 25% RDI of riboflavin, niacin, vitamin B6 and pantothenic acid can also be provided by 100g of red meat, but compared to pork it is a relatively poor source of thiamin. Liver is an excellent source of vitamin A and folate, but the levels in lean meat tissue are low. For all these vitamins, older animals tend to have higher concentrations, so the levels in beef are generally higher than those in veal, and mutton has more than lamb. Levels of vitamin D in meat are low and difficult to measure and have often not been included in food composition data previously. However recent assays of meat in New Zealand have reported levels of 0.10µg Vitamin D3/100g and 0.45µg 25-OHD3/100g in beef and levels of 0.04 and 0.93 µg/100g

respectively in lamb [19]. Given the higher biological activity of the 25-OH vitamin D, this means that 100g of cooked beef could provide 12% of the estimated adequate intake of 10µg/d for a 51-70 year old [7], and cooked lamb could provide more than 25%, and hence be an important source of this nutrient, especially for housebound elderly people.

Minerals
Beef and lamb meat are among the richest sources of the minerals iron and zinc, with 100g providing at least one quarter of daily adult requirements (Table 1). The iron in meat is mostly haem-iron which is well absorbed, and meat protein also appears to enhance the absorption of iron from meat. Similarly, absorption of zinc from a diet high in animal protein is greater than from plant foods, and the requirements for zinc may be as much as 50% higher for vegetarians [7]. Red meats are also good sources of selenium, providing over 20% RDI per 100g serve, although it is likely that selenium values in meat will be significantly affected by where animals feed and the time of the year of sampling. Lean meat is low in sodium with a potassium/sodium ratio of greater than five. The copper content in raw lean cuts range from 0.055 to 0.190mg/100g in beef and veal, 0.090 to 0.140mg/100g in lamb, and 0.190 to 0.240mg/100g in mutton, all significantly higher than values reported in British meat [20].

2.2 Meat based bioactive compounds
In addition to the traditional essential nutrients with defined requirements, there are a number of meat-based bioactive substances that have been studied for their potential beneficial effects [21].

Taurine
An amino acid in meat of particular interest is taurine. Meat is rich in taurine (110mg/100g in lamb and 77mg/100g in beef) [22] and meat is the most abundant dietary source. While taurine can be derived from methionine and cysteine metabolism, there have been suggestions that it should be considered a conditionally essential amino acid during lactation, during times of immune challenge, and may offer protection against oxidative stress [23, 24].

Carnitine
L-carnitine (beta-hydroxy-gamma-trimethyl amino butyric acid) transports long chain fatty acids across the inner mitochondrial membranes to produce energy during exercise. Although not an essential nutrient, needs appear to be increased during pregnancy and after strenuous exercise and a recommended intake of 24-81mg/d has been proposed [25]. It is found in skeletal muscle and is particularly abundant in sheep muscle at up to 209mg/100g [26] and in beef at around 60mg/100g [27].

Conjugated linoleic acid (CLA)
CLA has antioxidant and immunomodulatory properties and may also play a role in the control of obesity [28]. Since rumen bacteria convert linoleic acid to CLA, it is most abundant in the fat of ruminant animals, although CLA is also present in partially hydrogenated vegetable oils. The CLA content of meat is affected by several factors including breed, age and food composition [29]. It is mostly present in the fat component of red meat (approximately 1g/100g) but is also found in the muscle meat: 10-46mg/100g in raw meat and 30-100mg/100g in cooked red meat [17].

Endogenous antioxidants
Several endogenous compounds (including ubiquinone, glutathione, lipoic acid, spermine, carnosine, anserine) have been studied in skeletal muscle [30]. Both carnosine and anserine are antioxidative histidyl dipeptides and the most abundant antioxidants in meat. Carnosine is present at around 365mg/100g in beef [31] and 400mg/100g in lamb [22]. Because carnosine is absorbed into the plasma intact, it is a potentially important dietary antioxidant [32]. Coenzyme Q10 (ubiquinone) also has antioxidant properties and supplements have shown beneficial effects in some studies [33]. Levels in meat are estimated to be around 2mg/100g in both beef and sheep meat [31]. Glutathione is a component of glutathione peroxidise enzymes which have an important antioxidant role in the body. It may also play a role in immune response and enhancing iron absorption by contributing to the 'meat factor'. Glutathione levels in red meat are estimated to be 12-26mg/100g in beef [34] and most meats contain approximately twice the level of glutathione of poultry and up to ten times the content found in fish.

Creatine
Creatine and its phosphorylated derivative creatine phosphate play an important role in muscle energy metabolism and under some circumstances creatine supplements can enhance muscle performance [35]. Red meat contains approximately 350mg/100g [31] and is the principal dietary source for humans. Creatine in meat is readily absorbed [36], but typical intakes are unlikely to provide the levels of creatine used for supplementation of sports performance (up to 15g/day).

2.3 Nutrient composition of organ meats
Table 5 provides a comparison of the nutrient content of liver, kidney, heart, brains and tripe from beef and lamb. From this table the following general statements can be made:

- All organ meats (except tripe) are extremely rich in vitamin B12, with more than 100% RDI in 100g
- Liver is a rich source of protein iron, zinc, riboflavin, niacin, vitamin A, and folate
- Kidney is rich in protein, thiamin, riboflavin, iron, and a source of folate
- Heart is a good source of iron and zinc, but not as good as liver and kidney
- Brains and tripe are not particularly good sources of vitamins or minerals
- All organs meats are high in cholesterol, especially brains, and mostly low in sodium
- Liver is such a rich source of retinol that consumption of large amounts is not recommended in pregnancy.

3) Comparison of the composition of red meat and vegetarian protein sources
The Australian Guide to Health Eating recommends a healthy diet include 1-2 serves per day of meat or equivalents such as eggs, nuts or legumes [37]. However the vegetarian alternatives that are used as protein sources have very different nutritional profiles to red meat, as show in Table 6, which compares the percentage of an adult male daily requirement provided by 100g of food. Lean beef and lamb are better protein sources than all the options except cheese, and are mostly lower in sodium. The meats are higher in zinc and niacin than all the alternatives and also higher in omega-3 fats than the vegetable sources; a better source of vitamin B6 (except for the walnuts); richer in selenium (except in comparison to eggs); and are the best source of vitamin B12, which is absent entirely from the vegetable products. Egg, cheese and nuts are also much higher sources of total fat than lean beef or lamb.

Table 1. Nutrient composition (per 100g) of lean red meat [4-6]

	Beef	Veal	Lamb	Mutton	Adult Australian RDI
Moisture (g)	73.1	74.8	72.9	73.2	
Protein (g)	23.2	24.8	21.9	21.5	46-64
Fat (g)	2.8	1.5	4.7	4.0	-
Energy (kJ)	498	477	546	514	6.5-15.8MJ
Cholesterol (mg)	50	51	66	66	-
Thiamin (mg)	0.04	0.06	0.12	0.16	1.1-1.2
Riboflavin (mg)	0.18	0.20	0.23	0.25	1.1-1.6
Niacin (mg)	5.0	16.0	5.2	8.0	14-16
Vitamin B6 (mg)	0.52	0.8	0.10	0.8	1.3-1.7
Vitamin B12 (µg)	2.5	1.6	0.96	2.8	2.4
Pantothenic acid (mg)	0.35	1.50	0.74	1.33	4-6
Vitamin A (µg)	<5	<5	8.6	7.8	700-900µg RE*
Beta-carotene (µg)	10	<5	<5	<5	700-900µg RE*
Alpha-tocopherol (mg)	0.63	0.50	0.44	0.20	7-10
Sodium (mg)	51	51	69	71	460-920
Potassium (mg)	363	362	344	365	2800-3800
Calcium (mg)	4.5	6.5	7.2	6.6	1000-1300
Iron (mg)	1.8	1.1	2.0	3.3	8-18
Zinc (mg)	4.6	4.2	4.5	3.9	8-14
Magnesium (mg)	25	26	28	28	310-420
Phosphorus (mg)	215	260	194	290	1000
Copper (mg)	0.12	0.08	0.12	0.22	1.2-1.7
Selenium (µg)	17	<10	14	<10	60-70

*RE = retinol equivalents (= 1 µg retinol or 6 µg or beta-carotene)

Table 2 – Lean and separable fat from untrimmed raw boneless Australian red meat (mean weight) [3, 10]

Meat Cut	% Lean	% External Fat	% Internal Fat
Beef			
Topside roast	91	6	3
Silverside roast	89	7	4
Blade steak	88	6	6
Porterhouse steak	77	18	5
Stir fry	98	2	0
Scotch fillet	81	8	11
Veal			
Leg steak	99	0	1
Diced	98	2	0
Cutlet	93	1	6
Lamb			
Leg roast	83	11	6
Chump chop	75	15	10
Diced	98	2	0
Easy carve shoulder	77	12	11
Loin chop	63	29	8
Mutton			
Leg	85	9	6
Casserole	90	10	0

Table 3 – Fat and cholesterol content of trimmed raw and cooked Australian red meat [4]

Meat Cut	Total fat (g)	Cholesterol (mg)
Beef		
Diced, raw	2.7	54
Diced, cooked	3.0	77
Round steak, raw	1.7	62
Round steak, cooked	2.0	75
Topside roast, raw	4.7	35
Topside roast, cooked	2.8	62
Sirloin steak, raw	1.9	58
Sirloin steak, cooked	3.8	70
Scotch fillet, raw	2.8	58
Scotch fillet, cooked	4.5	70
Regular mince, raw	10.8	76
Regular mince, cooked	12.7	99
Low fat mince, raw	6.8	61
Low fat mince, cooked	9.0	81
Veal		
Leg steak, raw	1.5	57
Leg steak, cooked	1.9	85
Cutlet, raw	1.1	35
Cutlet, cooked	2.0	41
Lamb		
Diced, raw	5.2	78
Diced, cooked	6.5	96
Leg roast, raw	3.2	71
Leg roast, cooked	6.0	80
Easy carve shoulder, raw	4.3	54
Easy carve shoulder, cooked	5.4	86
Chump chop, raw	4.3	73
Chump chop, cooked	10.2	93
Cutlet, raw	6.7	67
Cutlet, cooked	8.6	96
Lamb mince, raw	6.9	61
Lamb mince, cooked	8.5	93
Mutton		
Leg roast, raw	4.2	76
Leg roast, cooked	11.4	130
Casserole, raw	3.8	56
Casserole, cooked	7.7	63

Table 4. Fatty acid profile of raw lean meats (g/100g edible portion)

Fatty Acid	Beef[1]	Veal[1]	Lamb[1]	Mutton[1]	Skinless chicken[2]	Lean pork[3]	White fish[4]	Oily fish[5]
C14:0	0.096	0.034	0.101	0.060	0.020	0.010	0.020	0.680
C15:0	0.012	0.006	0.016	0.011	0.000	0.000	0.000	0.070
C16:0	0.607	0.215	0.842	0.667	0.340	0.250	0.180	2.170
C17:0	0.028	0.009	0.051	0.036	0.010	0.000	0.000	0.050
C18:0	0.356	0.119	0.644	0.609	0.120	0.130	0.050	0.350
Total saturated	**1.149**	**0.409**	**1.730**	**1.464**	**0.500**	**0.400**	**0.300**	**3.320**
C14:1	0.025	0.007	0.004	0.003	0.000	0.000	0.000	0.000
C16:1	0.082	0.033	0.066	0.039	0.004	0.030	0.060	0.590
C18:1	1.103	0.356	1.995	1.370	0.620	0.390	0.110	2.190
C20:1	0.015	0.048	0.010	0.011	0.010	0.010	0.010	1.340
Total monounsaturated	**1.205**	**0.399**	**2.066**	**1.413**	**0.700**	**0.430**	**0.200**	**5.390**
C18:2 ω-6	0.204	0.090	0.321	0.339	0.210	0.120	0.010	0.250
C18:3 ω-3	0.048	0.022	0.072	0.107	0.010	0.010	0.000	0.130
C20:3 ω-6	0.020	0.012	0.009	0.009	0.008	0.003	0.000	0.000
C20:4 ω-6	0.076	0.056	0.094	0.101	0.030	0.019	0.040	0.050
C20:5 ω-3 (EPA)	0.031	0.028	0.028	0.044	0.005	0.000	0.048	0.913
C22:5 ω-3 (DPA)	0.051	0.033	0.044	0.053	0.009	0.006	0.021	0.194
C22:6 ω-3 (DHA)	0.006	0.003	0.013	0.020	0.009	0.004	0.111	1.118
Total polyunsaturated	**0.448**	**0.259**	**0.603**	**0.673**	**0.300**	**0.200**	**0.200**	**2.655**
Total ω-3	0.136	0.086	0.157	0.224	0.033	0.020	0.180	2.355
Total ω-6	0.300	0.244	0.424	0.449	0.258	0.148	0.050	0.250
Ratio ω-3/ ω-6	0.45	0.36	0.37	0.50	0.13	0.14	3.60	10.42

1. Average values from 2002 analyses of Australian red meat [17]
2. Values for raw lean chicken breast from NUTTAB 2006 [38]
3. Values for raw lean pork fillet from NUTTAB 2006 [38]
4. Values for raw flathead from NUTTAB 2006 [38]
5. Values for canned red salmon from NUTTAB 2006 [38]

Table 5. Selected nutrients (per 100g) in raw liver, kidney, heart, brain and tripe [1]

	Liver		Kidney		Heart		Brain	Tripe
	Beef	**Lamb**	**Beef**	**Lamb**	**Beef**	**Lamb**	**Lamb**	**Beef**
Protein (g)	20.0	21.4	18.2	17.1	18.2	17.8	12.3	13.2
Fat (g)	8.6	7.5	1.6	2.5	3.0	5.6	8.0	2.1
Saturated fat (g)	2.8	2.2	0.6	0.9	1.2	2.3	2.2	0.9
Long-chain omega-3 fat (mg)	561	361	47	103	54	102	574	20
Cholesterol (mg)	271	433	313	338	103	129	1352	82
Thiamin (mg)	0.23	0.24	0.40	0.56	0.50	0.61	0.14	0
Riboflavin (mg)	4.80	2.80	3.60	2.10	1.50	1.10	0.40	0.10
Niacin (mg)	9.4	10.9	6.5	7.6	6.9	5.9	5.1	0.2
Folate (µg)	290	230	98	28	3	2	3	5
Vitamin B12 (µg)	59	90	28	52	9	10	11	1
Retinol equivalents (µg)	13877	31400	155	93	10	0	0	0
Zinc (mg)	3.6	4.3	1.8	2.6	1.6	1.6	1.1	1.2
Iron (mg)	5.8	9.5	5.4	9.8	5.0	3.9	1.7	0.4
Magnesium (mg)	15	19	15	16	17	17	12	6
Sodium (mg)	78	67	160	190	91	82	120	100
Potassium (mg)	320	300	250	260	280	260	340	23

1. Folate values from US data [39]; all other values from NUTTAB 2006 [38]

Table 6. Percentage of male adult recommended dietary intake (RDI) or adequate intake (AI) provided by 100g of lean red meat and some vegetarian protein sources

	RDI/AI for male 31-50y	Beef[1]	Lamb[1]	Egg[2]	Cheddar cheese[2]	Baked beans salt reduced[2]	Walnuts[2]
Protein	64g	36	34	21	40	7	23
Long-chain omega-3 fat	160mg	50	53	111	55	0	0
Thiamin	1.2mg	3	8	8	3	4	28
Riboflavin	1.3mg	25	15	31	39	0	14
Niacin	16mg	31	70	0	<1	5	9
Vitamin B6	1.3mg	23	43	5	6	8	33
Vitamin B12	2.4µg	79	71	58	35	0	0
Pantothenic acid	6mg	12	13	34	7	<1	11
Vitamin A	900µg	<1	<1	25	43	<1	<1
Vitamin E	10mg	7	5	22	40	1	26
Phosphorus	1000mg	22	23	20	47	8	37
Zinc	14mg	30	31	9	26	4	18
Iron	8mg	24	25	26	3	20	31
Magnesium	420mg	6	6	2	7	6	36
Selenium	70µg	29	21	37	15	5	3
Sodium	920mg	6	7	13	72	23	<1
Potassium	3800mg	9	9	3	2	6	12

1. Average values from 2002 analyses of Australian red meat [4]
2. Values from NUTTAB 2006 [38]

References

1. Food Standards Australia New Zealand. *Food Standards Code - Volume 2*. Canberra: Information Australia, 2002.
2. Beilken S, Eustace E, Eustace R. *Composition of new meats - analyses and nutrient composition of innovative meat industries. RIRDC Publication No 07/036.* Canberra: RIRDC, 2007. Cited 25 April 2007. Available at: http://www.rirdc.gov.au/reports/NAP/07-036.pdf.
3. Williams P, Droulez V, Levy G et al. Nutrient composition of Australian red meat 2002. 1. Gross composition data. *Food Aust* 2006; **58**: 173-181.
4. Williams P, Droulez V, Levy G et al. Composition of Australian red meat 2002. 3. Nutrient profile. *Food Aust* 2007; **59**(in press).
5. Sadler M, Lewis J, Buick D. Composition of trim lamb. *Food Aust* 1993; **45**(Suppl): S2-12.
6. Sinclair A, Mann N, O'Connell S. *The nutrient composition of Australian beef and lamb*. Melbourne: RMIT, 1999.
7. National Health and Medical Research Council. *Nutrient Reference Values for Australia and New Zealand including Recommended Dietary Intakes*. Canberra: Commonwealth Department of Health and Ageing, 2006.
8. Bhutta Z. *Protein: digestibility and availability*. In: *Encyclopedia of Human Nutrition*. M Sadler, J Strain and B. Caballero (Editors). San Diego: Academic Press, 1999. p. 1646-1656.
9. Schaafsma G. The Protein Digestibility-Corrected Amino Acid Score. *J Nutr* 2000; **130**: 1865S-1867S.
10. Cobiac L, Droulez V, Leppard P et al. Use of external fat width to describe beef and lamb cuts in food composition tables. *J Food Comp Anal* 2003; **16**: 133-145.
11. Greenfield H, Kuo Y, Hutchison G et al. Composition of Australian foods. 33. Lamb. *Food Aust* 1987; **39**: 202-207.
12. Greenfield, H, Kuo Y, Hutchison G et al., Composition of Australian foods. 34. Beef and veal. *Food Aust* 1987; **39**: 208-215;227.
13. Higgs J. The changing nature of red meat: 20 years of improving nutritional quality. *Trends Food Sci Technol* 2000; **11**: 85-95.
14. Sinclair A, O'Dea K. The lipid levels and fatty acid compositions of the lean portions of Australian beef and lamb. *Food Technol Aust* 1987; **39**: 228-231.
15. Marmer W, Maxwell R, Williams J. Effects of dietary regimen and tissue site on bovine fatty acid profiles. *J Anim Sci* 1984; **59**: 109-121.
16. Howe P, Meyer B, Record S et al. Dietary intakes of long-chain omega-3 polyunsaturated fatty acids: contribution of meat sources. *Nutrition*, 2006; **22**: 47-53.
17. Droulez V, Williams P, Levy G et al. Nutrient composition of Australian red meat 2002. 2. Fatty acid profile. *Food Aust* 2006; **58**: 335-341.
18. Zeisel S, Niculescu M. *Choline and Phosphatidylcholine*. In *Modern Nutrition in Health and Disease*. M Shils et al. (Editors). Philadelphia: Lippincott Williams & Wilkins, 2006. p. 525-536.
19. Purchas R, Zou M, Pearce P et al. Concentrations of vitamin D3 and 2-hydroxyvitamin D3 in raw and cooked New Zealand beef and lamb. *J Food Comp Anal* 2007; **20**: 90-98.
20. Chan W, Brown J, Lee S et al. *Meat, Poultry and Game. Fifth Supplement to McCance & Widdowson's The Composition of Foods*. London: The Royal

Society of Chemistry and the Ministry of Agriculture Fisheries and Food, 1995.
21. Arihara K. Strategies for designing novel functional meat products. *Meat Sci* 2006; **74**: 219-229.
22. Purchas R, Rutherfurd S, Pearce P et al. Concentrations in beef and lamb of taurine, carnosine, coenzyme Q10, and creatine. *Meat Sci* 2004; **66**: 629-637.
23. Redmond H, Stapleton P, Neary P et al. Immunonutrition: the role of taurine. *Nutr Cancer* 1998; **14**: 599-608.
24. Bouckenooghe T, Remacle C, Reusens B. Is taurine a functional nutrient? *Curr Opin Clin Nutr Metab Care* 2006; **9**: 728-733.
25. Tanpaichitr V, Leelahagul P. Carnitine metabolism and human carnitine metabolism. *Nutrition* 1993; **9**: 246-254.
26. Mitchell M. Carnitine metabolism in human subjects 1. Normal metabolism. *Am J Clin Nutr* 1978; **31**: 293-306.
27. Shimada L, Sakuma Y, Wakamatsu J et al. Species and muscle differences in L-carnitine in skeletal muscles based on a new simple assay. *Meat Sci* 2004; **68**: 357-362.
28. Azain M. Conjugated linoleic acid and its effects on animal products and health in single-stomached animals. *Proc Nutr Soc* 2003; **62**: 319-328.
29. Dhiman T, Nam S, Ure A. Factors affecting conjugated linoleic acid content in milk and meat. *Crit Rev Food Sci Nutr* 2005; **45**: 463-482.
30. Decker E, Livisay S, Zhou S. *Mechanisms of endogenous skeletal muscle antioxidants: chemical and physical aspects*. In *Antioxidants in muscle foods*, E. Decker, C. Faustman and C. Lopez-Bote (Editors). New York: Wiley-Interscience, 2000. p. 25-60.
31. Purchas R, Busboom J. The effect of production system and age on levels of iron, taurine, carnosine, coenzyme Q10, and creatine in beef muscles and lover. *Meat Sci* 2005; **70**: 589-596.
32. Decker E, Ivanov V, Zhu B et al. Inhibition of low density lipoprotein oxidation by carnosine and histidine. *J Agric Food Chem* 2001; **49**: 511-516.
33. Overvad K, Diamant B, Holm L et al. Coenzyme Q10 in health and disease. *Eur J Clin Nutr* 1999; **53**: 764-770.
34. Jones D, Coates R, Flagg E et al. Glutathione in foods listed in the National Cancer Institute's health habits and history food frequency questionnaire. *Nutr Cancer*, 1992; **17**: 57-75.
35. Kreider R, Ferreira M, Wilson M et al. Effects of creatine supplementation on body composition, strength, and sprint performance. *Med Sci Sports Ex* 1998; **30**: 73-82.
36. Harris R, Nevill M, Harris D et al. Absorption of creatine supplied as a drink, in meat or in solid form. *J Sports Sci* 2002; **20**: 147-151.
37. Smith A, Kellett E, Schmerlaib Y. *The Australian Guide to Healthy Eating. Background information for nutrition educators*. Canberra: Commonwealth Department of Health, 1998.
38. Food Standards Australia New Zealand. *NUTTAB 2006. Online database of the nutritional composition of Australian foods*. Canberra: FSANZ, 2007. Cited 25 April 2007. Available at: http://www.foodstandards.gov.au/monitoringandsurveillance/nuttab2006/onlineversionintroduction/index.cfm

39. US Department of Agriculture, *USDA National Nutrient Database for Standard Reference. Release 19*. Washington DC: USDA, 2007. Cited 25 April 2007. Available at: http://www.nal.usda.gov/fnic/foodcomp/search/