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Composition of Australian red meat 2002. 2. Fatty acid profile

V. Droulez
University of Wollongong

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

G. Levy
University of Wollongong

T. Stobaus
National Measurement Institute, South Melbourne

A. Sinclair
RMIT University

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Abstract

Australian retail samples of nine beef, six lamb, four veal and two mutton cuts were purchased from 10 retail outlets (butchers and supermarkets) in different socio-economic areas of Sydney and Melbourne. The lean and fat components were analysed for contents of total and individual fatty acids. The content of total fatty acids was less than 5g/100g edible meat in the lean component of all cuts analysed. Saturated and monounsaturated fatty acids comprised, on average, 40% and 42% respectively of total fatty acids in the lean component of red meat cuts. The saturated fatty acid content of the lean component of red meat cuts varied from 0.3g to 1.9g/100g edible meat. Trans fatty acids (18:1 trans) varied from 22mg/100g in lean veal to 123mg/100g in lean lamb. Polyunsaturated fatty acids, mainly 18:2n-6, 20:4n-6, 18:3n-3, 20:5n-3 and 22:5n-3, ranged from 11% to 29% of total fatty acids. Levels of arachidonic acid ranged from 97mg/100g in lean mutton to 55mg/100g in lean veal. Docosapentaenoic acid content varied from 32mg/100g to 54mg/100g in the lean component of red meat cuts. There were no significant differences in the proportion of fatty acids between raw and cooked meat. Australian red meat, which is predominantly grass-fed, contains lower levels of total, saturated and trans fatty acids and higher levels of n-3 polyunsaturated fatty acids than meat from the UK or the US. Key words: Fatty acids; red meat, beef; veal; lamb; mutton; saturated fatty acid; monounsaturated fatty acid; polyunsaturated fatty acid; long chain omega 3 fatty acid; conjugated linoleic acid

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Authors:

Veronique Droulez MPH APD [1*]

Peter Williams PhD APD MAIFST [1]

Gina Levy PhD APD MAIFST [1]

Tim Stobaus BAppSc(Chem) [2]

Andrew Sinclair PhD FAIFST [3]

[1] Smart Foods Centre, University of Wollongong, Wollongong, NSW 2522, Australia

[2] National Measurement Institute (formerly Australian Government Analytical Laboratory), 51-65 Clarke Street, South Melbourne, Vic 3205, Australia

[3] RMIT University, GPO Box 2476V, Melbourne, Vic 3001, Australia

[*] Previously at Meat and Livestock Australia, Locked Bag 991, NSW 2059, Australia

Correspondence: Dr Peter Williams
Smart Foods Centre
University of Wollongong
Wollongong NSW 2052

Tel. 61 2 42214085
Fax. 61 2 42214844
Email: peter_williams@uow.edu.au

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Abstract

Australian retail samples of nine beef, six lamb, four veal and two mutton cuts were purchased from 10 retail outlets (butchers and supermarkets) in different socio-economic areas of Sydney and Melbourne. The lean and fat components were analysed for contents of total and individual fatty acids. The content of total fatty acids was less than 5g/100g edible meat in the lean component of all cuts analysed. Saturated and monounsaturated fatty acids comprised, on average, 40% and 42% respectively of total fatty acids in the lean component of red meat cuts. The saturated fatty acid content of the lean component of red meat cuts varied from 0.3g to 1.9g/100g edible meat. Trans fatty acids (18:1 trans) varied from 22mg/100g in lean veal to 123mg/100g in lean lamb. Polyunsaturated fatty acids, mainly 18:2n-6, 20:4n-6, 18:3n-3, 20:5n-3 and 22:5n-3, ranged from 11% to 29% of total fatty acids. Levels of arachidonic acid ranged from 97mg/100g in lean mutton to 55mg/100g in lean veal. Docosapentaenoic acid content varied from 32mg/100g to 54mg/100g in the lean component of red meat cuts. There were no significant differences in the proportion of fatty acids between raw and cooked meat. Australian red meat, which is predominantly grass-fed, contains lower levels of total, saturated and *trans* fatty acids and higher levels of n-3 polyunsaturated fatty acids than meat from the UK or the US.

Key words:

Fatty acids; red meat, beef; veal; lamb; mutton; saturated fatty acid; monounsaturated fatty acid; polyunsaturated fatty acid; long chain omega 3 fatty acid; conjugated linoleic acid

Introduction

Fatty acids play an important role in influencing health outcome. The role of saturated and *trans* fatty acids in increasing the risk of cardiovascular health, and polyunsaturated fatty acids (PUFA) in reducing risk, are well established (National Heart Foundation 1999). More recently, there have been reports of the beneficial effects of long chain n-3 PUFA in relation to other health outcomes (Din and others 2004). There is, therefore, a need for accurate and reliable data on the fatty acid composition of foods to facilitate further research on the contribution of fatty acids to health outcome as well as the formulation of nutrition recommendations.

Red meat is frequently consumed by the majority of Australians and therefore plays an important role in the Australian diet (Baghurst and others 2000; Li and others 2005). There is evidence that feeding regime impacts on the fatty acid profile of red meat. Grass-fed cattle have less saturated fatty acid and more long chain n-3 polyunsaturated fatty acids than grain-fed cattle (Marmer and others 1984, Sinclair and O'Dea 1987). In Australia, cattle and sheep are predominantly grass-fed. Consequently, there may be differences between countries in the relative contribution of red meat to fatty acid intake. Australian fatty acid databases mostly contain information on fish, fats and oils, due to lack of analytical data on many other foods (Mann and others 2003). The purpose of this study was to determine the fatty acid content of red meat available for purchase in Australia in order to gain an understanding of the health implications of Australian red meat consumption.

Materials and methods

Collection of meat samples

Nine beef, six lamb, four veal and two mutton cuts were purchased at random from 10 retail outlets (comprised of 6 supermarkets and 4 butchers) in different socio-economic areas of Melbourne and Sydney in June 2002. The samples were collected as part of a larger study of the gross composition of Australian red meat and the sampling, collection and cooking methods have been described in detail elsewhere (Williams and others, in press).

The nine beef cuts were rump steak, round steak, topside roast, silverside roast, sirloin steak (also called New York cut or Porterhouse steak), fillet steak, T-bone steak, scotch fillet (also called cube roll, rib-eye, or rib fillet steak) and blade steak. The six lamb cuts were forequarter chop, chump chop, loin chop, leg (bone-in) roast, Easy carve shoulder roast and lamb mini roast. The four veal cuts were leg steak, veal cutlet, stir-fry strips and diced veal. The two mutton cuts were baking leg and casserole.

Preparation of meat samples for analysis

Samples were transported chilled to the Australian Government Analytical Laboratory (AGAL) in Melbourne within 24 hours of purchase, where the samples were dissected as previously described (Williams and others, in press). Briefly, the gross composition process involved dissection of each sample into separable lean, total separable fat, or into external and internal separable fat where appropriate, and waste/bone/heavy

connective tissue components. Dissection was conducted as quickly as possible to minimise moisture loss.

Immediately following dissection, equal quantities from the lean component of each purchase of each retail cut were combined to form a composite sample of the purchase. Similarly, an equal quantity from the fat component of each purchase for each cut was combined to form a composite sample. The following cuts, derived from similar parts of the carcase, were pooled to form one sample of muscle meat: (1) topside and silverside roast; (2) fillet, New York, scotch fillet and T-bone (called Loin – pooled); (3) veal stir fry and diced; (4) lamb leg roast, mini roast and chump chop (called Leg); and (5) lamb forequarter chop and Easy Carve shoulder (called Forequarter cuts).

Samples were homogenized in a heavy-duty blender and stored in plastic samples containers with screw top lids, filled to a minimum headspace, in a –18°C freezer prior to fatty acid analysis. Each sample container was labelled with a sample description and a unique AGAL Laboratory Registration Number. The samples remained in frozen storage for up to one month prior to transport by same day courier, in insulated containers with ice, to RMIT University for analysis.

Analysis of fatty acid levels

Homogenates were thawed and analysed within a month of sample purchase. Each sample was analysed for contents of total and individual fatty acids on a g/g basis and determination of % moisture content. Each sample was analysed in duplicate. Moisture content was measured on the raw homogenates by an automated moisture

analyser (CEM Corp, USA) (Mann and others 1991). The fatty acid methyl esters were separated by capillary gas liquid chromatography (Li and others 1998). For methods used, precision and accuracy were validated and documented under standards established by the Association of Official Analytical Chemists (AOAC 2003).

Approximately 7 g portions of minced homogenized sample were extracted with 60 mL of chloroform-methanol (2:1 v/v) containing 10 mg/L of butylated hydroxytoluene and 5 mg of methyl tricosanate (C23:0, Nu-Chek-Prep, Elysian, MN, USA). Following extraction overnight and filtering, an 8 mL aliquot of the filtrate was mixed with 2 mL of 0.9% NaCl, shaken and left overnight at 4^{o}C to remove aqueous impurities. On the following day, the lower phase containing lipids was evaporated with pure nitrogen gas and fatty acid methyl esters (FAMES) of the total lipids were prepared by the addition of 1 mL of toluene and 3 mL of 0.9 M H_2SO_4 in methanol and heating the resulting solution at 70 ^{o}C for 2h with shaking at 15 min intervals. Upon cooling, 3 mL of petroleum ether and 3 mL of distilled water was added. This mixture was then thoroughly mixed and centrifuged for 10 min at 1000 rpm. The fatty acid containing upper phase was separated in a screw-capped tube, evaporated to dryness and reconstituted with petroleum ether. The fatty acid methyl esters were separated by capillary gas liquid chromatography using a 50 m x 0.32 mm fused silica bonded phase column (BPX70, SGE, Melbourne, Australia). Fatty acids were identified by comparison with standard mixtures of FAMES (Nu-Chek-Prep, Elysian, MN, USA), and the results were calculated using response factors derived from chromatographing standards of known composition.

Since there was little difference in the fatty acid profile of the fat component of red meat cuts from different carcase positions, or between the external and intermuscular fat, only the average content of the pooled fat components of beef, veal, lamb and mutton samples is reported.

Results

The percentage moisture and saturated fatty acid profiles, as a percentage of total fatty acids of the lean and fat components of beef, veal, lamb and mutton cuts, are presented in Table 1. Moisture levels reported for the fat and lean components of beef and veal and the lean component of lamb, were similar to those reported previously (Hutchinson et al, 1987; Sadler et al, 1993; Greenfield et al, 1987). For lamb, moisture levels in the fat component, were higher than those reported by Greenfield et al (1987) but lower than those reported by Sadler et al (1993). However, they are comparable to those reported for lamb in the United Kingdom (UK) (Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food 1995). It is unclear whether the variability in moisture levels for the fat component of lamb is due to differences in the density of lamb fat across different cuts or to a discrepancy in the analytical methodology. The sum of moisture and total fatty acids (excluding protein since it was not measured in this sub-study) for the fat component of the different lamb cuts varies between 83.5% and 101.4%.

The lean component of all beef, lamb and mutton samples contained less than 5g of total fatty acids per 100g edible portion and in the case of veal, less than 1.5g/100g. Saturated fatty acids comprised, 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 was palmitic acid (16:0) and about a third was stearic acid (18:0). In lamb and mutton the proportions of these two fatty acids was more similar. There was little variation between cuts in the proportion of fatty acids.

Overall, there were less than 2g saturated fatty acids per 100g edible portion in the lean component of raw Australian red meat. The leanest cuts, including all veal cuts and beef round, topside and silverside, contained less than 1g saturated fatty acids per 100g edible portion with as little 0.3g/100g for veal leg steak. The saturated fatty acid content of the fat component of raw Australian red meat was much higher than the lean component, and varied from 25 to 39g saturated fatty acid per 100g edible portion.

Table 2 describes the monounsaturated fatty acid profile of raw Australian red meat cuts as a percentage of total fatty acids. The proportion of monounsaturated fatty acids (MUFA) in Australian red meats was similar to that of saturated fatty acids, ranging from 40 to 50%. Lamb had a higher proportion of MUFA (47% of total fatty acids) in the lean component compared with beef, veal and mutton (approximately 40% of total fatty acids). Beef had a higher proportion of MUFA in the fat component (51% of total fatty acids) compared with veal, lamb and mutton (43%).

More than 80% of the MUFA found in raw Australian red meat, in both the lean and fat components, was oleic acid (18:1 cis). The *trans* fatty acid (18:1 *trans*) content of the lean component of red meat cuts was, on average, less than 3% of total fatty acids. The *trans* fatty acid content of red meats in both the lean and fat components reflected the total fatty acid content, i.e. the higher the total fatty acids, the higher the *trans* fatty acid content. The lean component of raw red meat cuts contained 2g or less MUFA per 100g edible portion. The leanest cuts, including all veal cuts and beef round, topside and silverside contained less than 1g MUFA per 100g edible portion

with as little as 0.3g/100g for veal leg steak. The fat components contained 21 to 37g MUFA per 100g edible portion, with mutton and veal containing lower levels than beef and lamb.

The polyunsaturated fatty acid (PUFA) content of raw Australian red meat cuts was around 0.5g per 100g edible portion in muscle meat and less than 7g per 100g edible portion in meat fat. The polyunsaturated fatty acid profile, as a percentage of total fatty acids, in the lean and fat components of raw Australian red meat cuts, is described in Table 3. The proportion of PUFA found in the lean component of Australian red meats ranged from 14% of total fatty acids in lamb to 24% in veal. Where the proportion of PUFA was lowest, as in the lean component of beef and lamb, the corresponding proportion of MUFA was higher. The proportion of PUFA in the fat component of raw Australian red meats was much lower than the lean component, generally containing less than 10% of total fatty acids.

The main polyunsaturated fatty acids found in red meat were linoleic acid (18:2 n-6), arachidonic acid (20:4 n-6) and the n-3 polyunsaturated fatty acids (linolenic, 18:3; eicosapentaenoic acid (EPA), 20:5; and docosapentaenoic acid (DPA), 22:5). Linoleic acid represented around a third of total polyunsaturated fatty acids in both muscle meat and meat fat of beef, veal, lamb and mutton. Arachidonic acid was concentrated in the muscle meat of Australian red meat, with no levels detected in meat fat. The proportion of arachidonic acid in muscle meat, which ranged from 2% to 6% of total fatty acids, reflected the total fatty acid content of the cut of meat. The proportion of linolenic acid in muscle meat varied from 1% to 3%, with the highest proportions reported in mutton. Some linolenic acid was detected in meat fat, with higher levels in

mutton and lamb fat than in beef and veal fat. A higher proportion of DPA than EPA was found in the muscle meat. Levels ranged from just over 3% to less than 1%. Some DPA but no EPA was detected in the meat fat. Some conjugated linoleic acid (CLA) was detected in Australian red meat, but mainly concentrated in the fat component. Consequently, levels of CLA in the muscle meat of Australian red meat cuts was low at less than 50 mg per 100 g edible portion.

The percentage moisture, amount of total fatty acids and saturated, monounsaturated and polyunsaturated fatty acid profiles, as a percentage of total fatty acids, in the lean and fat components of cooked beef, veal, lamb and mutton cuts, is presented in Table 4. As expected, the percentage moisture was lower and the amount of total fatty acids higher in the cooked meat compared to the raw meat. Percentage moisture of around 60 to 65% in the lean component and around 30% in the fat component of red meat, with the exception of veal fat, is similar to results from previous studies (Sadler and others 1993). There was a wide variation in the total fatty acid content between raw and cooked meat, which is probably explained by the sampling method used in this study.

The proportion of saturated fatty acid content in cooked red meat resembled that of raw meat, comprising an average of 40% of total fatty acids in the lean component and 48% in the fat component of red meat. The saturated fatty acid content of beef and lamb varied from 2.5 g to 0.9 g per 100 g edible portion in the lean component. It was slightly higher in lamb and mutton, varying from 4.3 g to 2.6 g per 100 g. The proportion of MUFA and PUFA in cooked meat resembled that of raw meat. The

monounsaturated fatty acid content of cooked red meat was generally less than 2 g per 100 g edible portion in the lean component.

Table 5 lists the concentration of selected specific fatty acids found in raw and cooked Australian red meat. Trans fatty acids (18:1 *trans*) in raw muscle meat varied from as little as 22 mg in veal to 123 mg in lamb. Levels in both raw and cooked muscle meat were higher in lamb and mutton than in beef and veal. Levels of CLA were higher in both raw and cooked meat fat, approximately 1 g per 100 g edible portion, than in muscle meat (where levels varied from 10 mg to 46 mg in raw meat and 30 to 100 mg in cooked meat). Higher levels of CLA were found in the muscle meat of lamb and mutton than in beef and veal. Arachidonic acid was concentrated in the muscle meat of red meat, varying in content per 100g edible portion from 97 mg in raw mutton to 55 mg in raw veal and from 101 to 131 mg per 100 g edible portion in cooked meat. Lamb and mutton muscle meat contained the highest levels of linolenic acid, 64 mg and 100 mg per 100g raw edible portion, respectively and 165 mg and 234 mg per 100g cooked edible portion, respectively. Levels were much lower in beef (41 mg/100 g in raw and 51 mg/100 g in cooked meat) and veal (19 mg/100 g in raw and 39 mg/100 g in cooked meat). Australian red meat contained higher levels of DPA and EPA than docosahexaehoic acid DHA. Levels of DPA ranged from 32 mg to 54 mg per 100g edible portion in raw muscle meat 64 mg to 91 mg per 100g edible portion in cooked muscle meat. The highest levels of long chain n-3 PUFA were found in raw and cooked mutton muscle meat.

Discussion

Although the samples in this study were collected from only two major metropolitan centres, it is likely that they are reasonably representative of the Australian food supply generally since a previous survey found there were no systematic differences in the retail supply of beef and lamb across socio-economic areas or states (Cobiac and others 2003). The sample size of 10 purchases per cut is consistent with previous studies with red meat (Sadler and others 1993) and general guidelines for nutrient analysis of foods (Greenfield and Southgate 1992).

The fatty acid profile of Australian red meat consisted of 40% saturated fatty acids, 42% monounsaturated fatty acids and 18% polyunsaturated fatty acids in the muscle meat and 48%, 45% and 7%, respectively, in the meat fat. These levels were slightly lower for saturated and higher for polyunsaturated fatty acids than reported previously for Australian retail cuts of lamb (Sadler and others 1993, Greenfield and others 1987a) and beef (Hutchison and others 1987; Greenfield and others 1987b) but similar to those reported for cuts prepared from specific pasture and grain-fed cattle and mid-loin chops (Sinclair and O'Dea 1987). Differences in analytical methods may account for some of these differences. Studies carried out in the 1980s used packed column chromatography, not capillary GLC and did not examine the presence of particular fatty acids that are now of nutritional interest, such as *trans* fats, CLA, EPA and DHA.

The fatty acid profiles for Australian red meat are similar to those reported for red meat in the UK (Royal Society of Chemistry and Ministry of Agriculture Fisheries

and Food 1995) and the United States (USDA 2004). However, the proportion of saturated fatty acids is slightly lower than those reported for beef in Italy (ranging from 43 to 49% of total fatty acids) (Carnovale and Nicoli 2000).

Saturated fatty acids are concentrated in the fat component of red meat, with less than 2 g per 100 g edible portion found in the raw muscle meat. These levels are lower than those reported in the UK, where trimmed lean beef contains on average 2.2g/100g saturated fatty acids (Royal Society of Chemistry and Ministry of Agriculture Fisheries and Food 1995). In the US, levels are reported to be between 1.2g/100g and 4g/100g depending on the grade of beef and the fat trim (USDA, 2004). Lean Australian red meat, with little visible meat fat, is therefore not an important source of saturated fats. Studies have shown that blood cholesterol levels can be reduced when consuming up to 500 g of lean Australian red meat as part of a low saturated fat diet (O'Dea and others 1990, Morgan and others 1993).

Trans fatty acids are formed by biohydrogenation of dietary PUFA in the rumen, converted from the *cis* configurations of 18:1 and 18:2 (commonly found in feed grains) to the *trans* form. However, only a small percentage is converted. *Trans* fatty acids found predominantly in Australian red meat are *trans* 11-18:1. The *trans* fatty acids produced as a result of hydrogenation of oils, which are considered risk factors for cardiovascular disease, are a mixture of 9-, 10- and 11- *trans*, and 18:1 isomers and hence different to those found in red meat (Mansour & Sinclair 1993). There is a wide variation in the *trans* fatty acid composition of meat, probably as a result of differences in feeding practices (Aro and others 1998). The levels of *trans* fatty acids reported in this study are consistent with those found in grass-fed beef for rump, blade

and strip loin cuts (Ponnampalam and others in press). Higher levels of *trans* fatty acids have been reported in grain-fed compared to grass-fed beef for rump, striploin and blade steak, possibly due to increased intake of total PUFA in grain feeding (Ponnampalam and others in press). *Trans* fatty acids are higher in the fat than in the lean component of red meat. Consequently, the total *trans* fatty acid content of the lean component of red meat is low, ranging from 22 mg in veal to 123 mg in lamb. This is consistent with data from the UK where trimmed raw lean lamb, which is higher in fat, contains 0.6g per 100g of *trans* fatty acids, whereas lean beef contains 0.1g per 100g (Royal Society of Chemistry and Ministry of Agriculture Fisheries and Food 1995).

Previous analytical methods did not have low enough levels of reporting to detect the low levels of long chain PUFA in red meat. Hence, earlier studies have underestimated the levels of EPA, DPA and DHA in Australian red meat (Sadler and others 1993). Levels of EPA, DPA and DHA in UK food tables for lean trimmed beef are on average 0.01, 0.02 and 0g/100g for beef, and 0.02, 0.03 and 0.01 for lamb, respectively (Royal Society of Chemistry and Ministry of Agriculture Fisheries and Food 1995). Levels reported in US beef are negligible. Levels found in Australian red meat in this study were slightly higher, possibly due to the predominant use of pasture-grazing production systems in Australia. Typically, grass contains 60% linolenic acid and only 10-20% linoleic acid compared with grain, which is rich in linoleic acid and low in linolenic acid. The higher linolenic acid content of the pasture feed allows for conversion to EPA and DPA (Sinclair & O'Dea 1987).

The levels of EPA, DPA and DHA found in this study are consistent with those reported in grass-fed rump, striploin and blade steaks (Ponnampalam and others in press). Since the levels of long chain PUFA found in Australian beef, veal and lamb muscle meat are greater than 30 mg per serving (135g) of red meat, they are considered a source of long chain n-3 polyunsaturated fatty acids according to Australian food regulations (Food Standards Australia New Zealand 2004). Mutton muscle meat, which has more than 60 mg 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 (Meyer and others 2003).

Levels of arachidonic acid found in this study were slightly higher than those reported previously (Sinclair and O'Dea 1987). They were also higher than those reported in UK lean trimmed beef and lamb which are, on average, 0.02g per 100g (Royal Society of Chemistry and Ministry of Agriculture Fisheries and Food 1995) and in US beef (USDA 2004). The cause of these differences may be analytical or unknown. There has been concern that the arachidonic acid content of red meat may increase the pool of tissue arachidonic acid and thereby increase the risk of platelet aggregation and thrombosis. However, it has been demonstrated that diets which double the usual 20:4n-6 intake using white meat (175g-330g/day) or red meat (275-530g/day) were not associated with increased platelet aggregation or thromboxane production (Mann and others 1997).

The proportion of fatty acids found in raw red meat resembled those found in cooked meat. However, the content of fatty acids varied between some raw and cooked cuts in ways that were not explained by differences in the percentage moisture. Since raw and cooked samples were randomly selected from the retail supply, it is possible that they were not derived from the same carcase, explaining differences in fatty acid content between raw and cooked samples for some cuts. To avoid this error in future, it is recommended raw and cooked samples be derived from the same carcase.

This study provides updated, more detailed data on the fatty acid profile of red meat retail cuts in Australia. Since Australian red meat is predominantly grass-fed, it contains lower levels of total, saturated and *trans* fatty acids and higher levels of n-3 polyunsaturated fatty acids than red meat which is mainly grain-fed asin the US and UK. Care is therefore required when interpreting epidemiological findings related to health outcomes from studies conducted in other countries where there are differences in the nutrient composition of red meat. According to these data, lean Australian red meat makes a useful contribution to a healthy diet, particularly in terms of its contribution to the intake of long chain n-3 polyunsaturated fatty acids.

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Table 1
Moisture (%), total fatty acids (g per 100g edible meat) and saturated fatty acid profile (% total fatty acids) of raw Australian red meat [1]

	Moisture %	Total fatty acids (g/100g edible meat)	14:0 %	15:0 %	16:0 %	17:0 %	18:0 %	Total SFA[5] %
Beef								
Muscle Meat:								
Rump	73.0	3.2	2.6	0.4	21.8	1.0	13.2	41.5
Round	74.0	1.5	1.6	0.3	20.1	0.9	14.0	39.7
Topside/ silverside	74.6	1.9	2.6	0.5	22.7	1.2	12.5	41.4
Loin – pooled[2]	71.9	4.5	3.4	0.5	23.1	1.2	12.9	42.9
Blade	73.5	3.0	4.3	0.5	21.6	0.9	11.6	41.1
Meat Fat – pooled	25.3	72.2	4.6	0.6	25.0	1.2	12.4	44.8
Veal								
Muscle Meat:								
Leg steak	76.4	0.8	2.2	0.4	17.9	0.7	10.3	34.6
Cutlet	75.6	1.0	3.7	0.8	22.5	0.9	11.7	42.1
Stirfry/Diced	76.4	1.4	3.6	0.5	20.4	0.9	11.4	38.6
Meat Fat-pooled	36.5	49.9	6.2	1.4	23.8	1.5	17.7	51.4
Lamb								
Muscle Meat:								
Leg - pooled[3]	73.2	4.2	2.1	0.4	18.3	1.2	13.4	37.2
Loin	73.7	4.3	2.2	0.3	19.5	1.2	16.2	41.0
Forequarter cuts - pooled[4]	73.7	4.7	2.6	0.4	19.6	1.1	14.3	39.8
Meat Fat-pooled	19.0	80.1	4.2	0.8	20.8	1.7	20.1	48.4
Mutton								
Muscle Meat:								
Leg	74.2	3.0	1.6	0.3	18.5	0.9	16.4	40.0
Casserole	73.5	4.1	1.8	0.3	19.1	1.1	18.4	42.5
Meat Fat-pooled	39.3	53.4	2.7	0.7	20.7	1.6	20.9	47.4

[1] Data shown are means of duplicate analyses on pooled samples as described in methods
[2] Loin - pooled = Fillet, New York, Scotch fillet and T-Bone
[3] Leg – pooled = Leg roast, Mini roast and Chump chops
[4] Forequarter cuts – pooled = Forequarter chops and Easy carve shoulder
[5] The additional saturated fatty acids represented in the total are small amounts of 22:0 and single branched saturates.

Table 2
Monounsaturated fatty acid profile (% total fatty acids) of raw Australian red meat[1]

	14:1 %	16:1 %	18:1cis %	18:1 trans %	Total MUFA %
Beef					
Muscle Meat:					
Rump	0.6	3.0	36.5	2.5	42.6
Round	0.3	2.1	35.7	1.9	40.0
Topside/ silverside	0.6	2.8	37.4	3.4	44.2
Loin – pooled[2]	0.9	3.3	37.4	3.0	44.6
Blade	1.0	3.4	35.8	2.1	42.3
Meat Fat-pooled	1.7	4.5	41.5	3.4	51.0
Veal					
Muscle Meat:					
Leg steak	0.6	2.9	31.3	1.9	36.7
Cutlet	0.8	3.2	28.3	2.1	34.4
Stirfry/Diced	0.9	3.2	34.6	2.2	40.8
Meat Fat-pooled	0.9	2.1	33.9	5.9	42.7
Lamb					
Muscle Meat:					
Leg - pooled[3]	0.1	1.6	44.2	2.6	48.5
Loin	0.1	1.4	43.1	3.0	47.6
Forequarter cuts - pooled[4]	0.1	1.5	40.4	2.7	44.8
Meat Fat-pooled	0.1	1.3	35.7	6.0	43.1
Mutton					
Muscle Meat:					
Leg	0.1	1.2	35.4	3.0	39.7
Casserole	0.1	1.0	36.1	2.7	39.9
Meat Fat-pooled	0.1	1.2	37.0	4.9	43.2

[1] Data shown are means of duplicate analyses on pooled samples as described in methods
[2] Loin - pooled = Fillet, New York, Scotch fillet and T-Bone
[3] Leg – pooled = Leg roast, Mini roast and Chump chops
[4] Forequarter cuts – pooled = Forequarter chops and Easy carve shoulder

Table 3
Polyunsaturated fatty acid profile (% of total fatty acids) of raw Australian red meat[1]

	18:2 n-6 %	18:2 Trans %	CLA[5] %	20:3 n-6 %	20:4 n-6 %	18:3 n-3 %	18:3 Trans %	20:5 n-3 %	22:5 n-3 %	22:6 n-3 %	Total PUFA[6] %
Beef											
*Muscle meat***:**											
Rump	5.6	0.5	0.8	0.7	2.8	1.9	0.3	1.0	1.7	0.2	15.9
Round	8.0	0.4	0.5	1.0	3.6	1.7	0.3	1.5	2.3	0.3	20.2
Topside/ silverside	6.1	0.4	0.4	0.7	2.9	0.5	0.3	0.7	1.5	0.2	14.4
Loin – pooled[2]	5.4	0.5	0.7	0.5	1.7	1.1	0.3	0.7	1.1	0.2	12.4
Blade	5.5	0.6	0.9	0.7	2.5	1.8	0.3	1.6	2.0	0.3	16.6
Meat fat – pooled	1.6	0.9	0.9	0.0	0.0	0.5	0.2	0.0	0.0	0.0	4.2
Veal											
Muscle meat:											
Leg steak	8.4	0.4	0.9	1.3	6.4	2.3	0.3	3.4	3.6	0.3	28.7
Cutlet	6.2	0.4	1.0	1.0	5.2	1.8	0.2	3.0	3.2	0.2	23.5
Stirfry/Diced	6.8	0.4	0.8	1.1	4.3	1.5	0.2	1.7	2.4	0.4	20.6
Meat fat - pooled	1.2	1.1	2.5	0.0	0.0	0.8	0.2	0	0.2	0.0	5.9
Lamb											
Muscle meat:											
Leg - pooled[3]	6.1	0.8	1.0	0.2	2.5	1.1	0.4	0.5	0.9	0.3	14.3
Loin	4.5	0.7	0.9	0.2	1.9	1.0	0.3	0.6	0.9	0.2	11.4
Forequarter cuts - pooled[4]	5.7	1.0	1.2	0.2	2.0	2.2	0.3	0.8	1.2	0.4	15.4
Meat fat – pooled	2.5	2.0	1.7	0.0	0.0	1.8	0.2	0.0	0.3	0.0	8.5
Mutton											
Muscle meat:											
Leg	8.8	0.7	0.9	0.3	3.7	1.9	0.3	1.1	1.6	0.6	20.3
Casserole	6.0	1.1	0.8	0.2	2.0	3.5	0.3	1.4	1.4	0.5	17.6
Meat fat – pooled	3.0	2.1	1.3	0.0	0.0	2.5	0.3	0.0	0.3	0.0	9.3

[1] Data shown are means of duplicate analyses on pooled samples as described in methods
[2] Loin - pooled = Fillet, New York, Scotch fillet and T-Bone
[3] Leg – pooled = Leg roast, Mini roast and Chump chops
[4] Forequarter cuts – pooled = Forequarter chops and Easy carve shoulder
[5] CLA = conjugated linolenic acid
[6] The additional polyunsaturated fatty acids represented in the total are small amounts of 20:2n-6 and 22:4n-6.

Table 4.
Moisture (%), total fatty acids (g per 100g edible meat) and saturated, monounsaturated and polyunsaturated fatty acid profile (% total fatty acids) of cooked Australian red meat [1]

	Moisture %	Total fatty acids (g/100g edible meat)	Total SFA %	Total MUFA %	Total PUFA %
Beef					
Muscle Meat:					
Rump, grilled	60.5	6.3	38.9	46.8	14.3
Round, grilled	66.0	4.9	39.8	46.6	13.6
Topside/silverside, roasted	65.4	3.1	32.6	51.2	16.2
Loin, grilled pooled[2]	61.9	4.9	37.9	49.2	13.0
Blade	61.1	4.3	38.5	47.7	13.8
Meat Fat – pooled	30.3	66.1	41.4	53.7	4.9
Veal					
Muscle Meat:					
Leg steak, grilled	64.4	2.8	33.1	44.4	22.5
Cutlet, grilled	65.6	2.2	47.8	34.9	17.2
Stir-fry/Diced, dry-fried	64.9	2.9	43.4	36.5	20.2
Meat Fat-pooled	53.2	41.8	55.0	39.4	5.7
Lamb					
Muscle Meat:					
Leg, roasted - pooled[3]	66.4	6.4	40.4	44.5	15.0
Loin, grilled	62.0	6.9	42.0	44.0	14.1
Forequarter cuts, roasted or grilled – pooled[4]	60.1	10.9	42.7	45.3	12.0
Meat Fat-pooled	29.0	64.6	50.0	42.3	7.7
Mutton					
Muscle Meat:					
Leg, roasted	54.3	8.1	40.2	46.0	13.8
Casserole, cooked in water	62.3	9.5	39.2	44.5	16.3
Meat Fat-pooled	33.6	63.5	44.6	47.7	7.7

[1] Data shown are means of duplicate analyses on pooled samples as described in methods. Cooking methods are described in detail in Williams, Droulez, Martin & Stobaus (in press)
[2] Loin - pooled = Fillet, New York, Scotch fillet and T-Bone
[3] Leg – pooled = Leg roast, Mini roast and Chump chops
[4] Forequarter cuts – pooled = Forequarter chops and Easy carve shoulder

Table 5
Content of specific fatty acids (mg/100 g edible portion) in raw and cooked Australian red meat[1]

	18:1 trans	CLA[2]	20:4 n-6	18:3 n-3	EPA 20:5 n-3	DPA 22:5 n-3	DHA 22:6 n-3
Muscle Meat – raw							
Beef	75	20	70	41	29	45	6
Veal	22	10	55	19	28	32	7
Lamb	123	46	93	64	27	45	13
Mutton	102	31	97	100	46	54	19
Muscle Fat – raw							
Beef	2,428	663	0	385	0	32	0
Veal	2,957	1,224	0	379	0	82	0
Lamb	4,850	1,325	0	1,444	0	204	0
Mutton	2,659	712	0	1,159	0	143	0
Muscle Meat – cooked							
Beef	89	33	106	51	50	78	11
Veal	66	29	101	39	52	64	15
Lamb	281	100	111	165	50	72	23
Mutton	312	110	131	234	88	91	42
Muscle Fat – cooked							
Beef	2,171	821	0	451	0	46	0
Veal	2,064	785	0	300	0	142	0
Lamb	2,988	846	0	1,150	0	185	0
Mutton	3,091	846	0	988	0	168	0

[1] Data shown are means of duplicate analyses on pooled samples as described in methods
[2] CLA = conjugated linoleic acid