openUP (December 2007)

The nutrient composition of South African lamb (A2 grade)

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Abstract

Dorper and Merino lamb carcasses of the A age group with a fat code 2 (±7% SCF) from three main production areas in South Africa were used for this study. The right sides of the carcasses were used to determine the raw nutrient and physical (carcass) composition of each cut as well as for the whole carcass by calculation. Three cuts (shoulder, loin and leg) from the left side were cooked in order to determine the nutrient composition thereof. Nutrients showing the greatest differences between raw and cooked treatments, were protein, total fat, C16:0 saturated fatty acid (SFA) and C18:1n9c monounsaturated fatty acid (MUFA). Moisture losses due to cooking resulted in an increase in the protein and cholesterol concentrations of the cooked cuts. Iron content was lower in the cooked loin cut but increased in the cooked leg cut when compared to the corresponding raw cuts. The vitamin B content of all three cooked lamb cuts was lower, although not significantly so, than that of the corresponding raw cuts. Lamb is a good source of protein, iron and the B vitamins, especially vitamin B_{12} when cooked.

Article Outline

A knowledge of the chemical composition of foods is the first essential in dietary treatment of disease or in any quantitative study of human nutrition (McCance and Widdowson, 1940).

1. Introduction

As in many other countries, South Africa is actively involved in analysing foods for the compilation of food composition data. Currently, only 41% of all South African food values in the Medical Research Council's (MRC) tables are derived from South African foodstuffs (South African Food Composition Data (SAFCoD), 2000). The current data on mutton (lamb and sheep) that appears in the MRC's food composition tables of 1999, are derived from the United States Department of Agriculture (USDA) database (Sayed et al.,

1998). These data are not directly applicable and therefore it is appropriate that South Africa compiles sound scientific nutrient data for South African lamb and mutton.
It is important that different countries have their own food composition tables for meat cuts (and products) such as lamb, mutton, beef and pork. The reason being, that different techniques are used to cut carcasses into primal cuts. Different age groups and fat codes of the animals in various countries make the interpretation of the results difficult (Schönfeldt, 1998) as the composition of the carcasses has a direct influence on the nutrient content thereof. The difference in climate, soil content and water composition of the various regions furthermore affects the nutrient content (specifically the minerals and vitamins) of the animal feed, as well as the production of vitamin D in the meat itself (Greenfield and Southgate, 2003). Table 1 provides a comparison and variation of macro- and micro-nutrients when different databases are used, and illustrates that the use of different food composition tables may cause conflicting interpretation of dietary intake data. For instance, the iron content suggests that South African lamb is, on average slaughtered at a younger age than that of the United States of America's and British values and substantially younger than that of the Australian and New Zealand's. Iron content of meat is positively correlated with the age of the animal (Lawrie, 1998).

Table 1.

Nutrient values in lean lamb, expressed per 100 g cooked edible portion, for selected countries

Nutrients	**Unit**	**South Africa**[a]	**USA**[b]	**UK**[c]	**Australia**[d]	**New Zealand**[e]
		Cooked leg and shank	**Cooked leg roasted, lean and fat**	**Cooked lamb roast**	**Cooked fresh leg and shank half**	**Cooked leg (shank and sirloin)**
		Lean (±7% SCF)	**Lean and fat**	**90% meat**	**Trimmed to $\frac{1}{8}$ in fat**	**12% separable fat**
		100 g	**3 oz/85 g**	**100 g**	**100 g**	**100 g**
Proximate analysis						
Moisture	g	66.03	57	58.70	59.2	63.92
Protein (*N*×6.25)	g	24.46	22	24.30	29.3	27.68
Fat	g	7.67	14	13.30	11.9	7.01
Ash	g	1.05	—	—	1.10	1.52
Food energy (calculated)	kJ	722	931	905	937	757
Minerals						
Magnesium (Mg)	mg	23	—	24	19	21
Potassium (K)	mg	303	266	350	290	183
Sodium (Na)	mg	62	56	61	66	45
Zinc (Zn)	mg	1.71	—	4.5	4.5	4.04
Iron (Fe)	mg	1.20	1.7	1.9	2.4	2.24

Nutrients	Unit	South Africa[a]	USA[b]	UK[c]	Australia[d]	New Zealand[e]
		Cooked leg and shank	**Cooked leg roasted, lean and fat**	**Cooked lamb roast**	**Cooked fresh leg and shank half**	**Cooked leg (shank and sirloin)**
		Lean (±7% SCF)	**Lean and fat**	**90% meat**	**Trimmed to $\frac{1}{8}$ in fat**	**12% separable fat**
		100 g	**3 oz/85 g**	**100 g**	**100 g**	**100 g**
Vitamins						
Thiamin (B_1)	mg	0.06	—	0.15	0.06	0.12
Riboflavin (B_2)	mg	0.05	0.23	0.27	0.25	0.50
Niacin (B_3)	mg	1.63	5.6	4.5	4.5	7.51
Pyridoxine (B_6)	mg	0.10	—	0.22	—	0.14
Cyanocobalamin (B_{12})	µg	1.06	—	4	—	2.63
Lipids						
SFA	g	4.07	5.9	6.1	6.1	3.05
MUFA	g	3.16	5.9	5.3	4.3	2.75
PUFA	g	0.29	1.0	0.7	0.2	0.41
Cholesterol	mg	92	79	98	109	10063

SCF: subcutaneous fat; SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; — :unreliable values omitted, currently being re-analysed.

[a] Data from this study.

[b] Gebhardt and Thomas (2002).

[c] Chan et al. (1996).

[d] Lewis et al. (1995, vol. 1).

[e] United Stated Department of Agriculture (1989).

Another aspect of nutrition is food choices, which have a direct impact on a person's health status. These choices are repeated over a long period (years or decades) and have major positive or negative health effects (Kruger et al., 2003). Therefore, in order to evaluate a person's food intake, according to the Recommended Dietary Allowance (RDA), the nutritional composition of the diet is calculated by making use of food composition databases, either in computerised software or printed form. This information provides the average nutrient content for a given amount of food, based on the chemical analysis of a number of food samples. Information on the nutrient content of a particular food can also be used as a standard reference to determine nutrients obtained from the foodstuff consumed throughout a country (Latham, 1997).

In developing countries, such as in South Africa, one of the major health concerns is the poor nutrient content, specifically micronutrients, of the diet. Iron deficiency resulting in anaemia, is the most common deficiency in the world that causes ill health. Data from the South African National Food Consumption Survey (Steyn et al., 2000) showed that children aged 1–9 years had low mean intakes of iron, protein, B-vitamins and minerals such as zinc and iodine. Consequently, nutrient deficiencies are widespread in all societies in South Africa.

Certain segments of our population are consuming significant amounts of lamb, and yet there is a lack of comprehensive, South African nutrient composition data on lamb. Following the need for data on the composition of South African lamb and mutton, as identified by the SAFCoD, the Animal Nutrition and Animal Products Institute of the Agricultural Research Council, Irene initiated a research focus area in 1988 to determine the nutrient content of South African animal products. Therefore, the aim of this research was to determine the nutrient composition of South African lamb in order to incorporate the data into the Food Composition Tables of the Medical Research Council of South Africa.

2. Materials and methods

2.1. Sampling

The South African classification system (National Department of Agriculture, 1990, p. 9–14) is designed to describe carcasses according to tissue composition. To this end, age is described according to the number of permanent incisors with age class A=0 teeth, AB=1–2 teeth, B=3–6 teeth and C=more than 6 teeth, while carcasses are grouped into 6 fat classes by means of visual appraisal (fatness class from 0=no fat to 6=excessively over fat). According to the fatness classification (National Department of Agriculture, 1990) an A2 lamb can have at least 1 mm, but not more than 4 mm fat, and more than 5.6% but not more than 8.5% subcutaneous fat (SCF) (average of 7% SCF).

Three wholesale cuts (leg, loin, shoulder) of South African lamb (Dorper and Merino) of an A-age group (0 incisors) with a fat code of 2 (lean=1–4 mm fat with ±7% SCF) were selected. The nutrient content of meat and fat of each of the three wholesale cuts of one side (right) were analysed for raw nutrient values and three wholesale cuts of one side (left) were analysed for cooked nutrient values.

The A2 class lamb carcasses [(lean animals (±7% SCF) with no incisors)] were selected in co-operation with the South African Meat Industry Company (SAMIC) and the Red Meat Producers Organization (RPO). Market share was used as the main factor in the selection of the two breeds. The attributes used were selected based on the fact that sheep are drawn from main production areas, supplying the main abattoirs. The meat samples, incorporated in the study, comprised of the most commonly consumed carcasses in South Africa (Japie van der Westhuizen, personal communication, 2003), namely Dorper (n=9) and Merino (n=9) carcasses of the A age group with a fatness level of 2 (±7% SCF).

Sheep slaughtered at these abattoirs are drawn from the three main production areas in South Africa namely the Karoo, Kalahari and Ermelo districts. The carcasses are classified according to the South African classification system at the abattoirs. The lambs were slaughtered using standard commercial procedures during four consecutive weeks. After selection the carcasses were transported in a refrigerated truck (4–6 °C) to the Meat Industry Centre of the ARC-ANPI, Irene. Upon arrival all the carcasses were weighed, covered with plastic wrap to prevent moisture loss and chilled at 4 °C overnight and dissected the following day. The lamb carcasses consisted of the skinned, eviscerated body from which the head and feet were removed. Carcasses were sectioned down the vertebral column with a band saw and then subdivided into the following primal cuts: neck, thick rib, flank, shoulder, breast, rib, loin, chump, leg and shank. The right sides of the carcasses were used to determine the physical cut composition as well as by calculation for the whole carcass (these data will be presented in another article). The raw nutrient contents for some macro- and micronutrients for each cut were also determined. Three cuts, representing the most commonly consumed cuts, (shoulder, loin and leg) from the left sides were used to determine the cooked nutrient composition thereof. These cuts were vacuum packed and frozen at −20 °C until the cooking process commenced. The raw and cooked nutrient data of the three cuts was compared. The assumption, as confirmed by Kirton et al. (1962), is that the composition of the two sides is similar.

2.2. Sample preparation

2.2.1. Right sides

A trained deboning team was responsible for the physical dissection of the raw lamb carcasses that were weighed prior to being divided into primal cuts. The cuts from the right sides were dissected by knife into three portions namely meat [muscle+intramuscular fat (i.e. fat within the muscle)], bone and subcutaneous fat, in an environmentally controlled (10 °C) abattoir.

2.2.2. Left sides

The shoulder, loin and leg cuts were thawed, weighed and cooked according to standardised cooking methods (leg, combination dry and moist heat cooking method; loin, dry heat cooking method; shoulder, moist heat cooking method) in identical Mielé ovens at 160 °C, to an internal temperature of 71 °C, measured in the geometrical centre of the cut (American Meat Science Association, 1995). It was then dissected into three portions namely meat (muscle+intramuscular fat), bone and subcutaneous fat, in an environmentally controlled (10 °C) abattoir by the team of experienced dissectors.

2.3. Preparation of the raw and cooked composite samples

In order to comply with the new Draft Regulations relating to the Labeling and Advertising of Foodstuffs, as part of the Foodstuffs, Cosmetics and Disinfectants Act (1972, http://0-www.doh.gov.za.innopac.up.ac.za:80/department/dir_foodcontr.html), it was proposed that a composite of three carcasses would be used as a basis of the study. The use of composite samples for analysis rather than individual samples is justified by budgeting constraints and is an accepted approach in food composition studies (Greenfield and Southgate, 2003). Three wholesale cuts (leg, loin, shoulder) were selected. The meat and fat of each of the three wholesale cuts of one side (right) were analysed for raw and three wholesale cuts of one side (left) were analysed for cooked nutrients (proximate analysis, vitamins, minerals, fatty acids and cholesterol). To prepare the composite samples, the meat and fat, respectively, of all the replications of each raw and cooked cuts were combined and cubed, thoroughly mixed and then minced, firstly through a 5 mm and then through a 3 mm mesh plate. Samples of 300 g meat and separable fat were homogenised with an Ultra Turrax T25 homogeniser after mincing to ensure a proper homogenised sample. These samples were then either placed in glass bottles prior to being frozen, or into aluminium trays covered with a vacuum bag prior to being freeze-dried.

2.4. Analyses

All the analytical procedures (Table 2) for the nutrient content of the lamb samples were done on a double blind basis in the laboratories (ISO/IEC 17025:2005) that form part of the South African National Accreditation Services (SANAS). Control samples form part of the daily routine in these laboratories to assure the quality of results. On the operational level, all sampling were representative and handled with utmost accuracy. A proper sampling plan was followed with representative samples from each area and sufficient replications of each sample were used to ensure statistically reliable and valid data.

Table 2.

Methods used for the nutrient analyses of raw and cooked South African lamb

Analyses	**Method**
Water	Association of Official Analytical Chemists (2005) method 950.46
Ash	Association of Official Analytical Chemists (2005) method 920.153
Protein	International Dairy Foundation Standard 20B (1993)
Fat	International Dairy Foundation Standard 20B (1996)
Energy	Bomb calorimeter to calculate
Minerals	Ion chromatography (Dionex System 20001, 1988)
Water-soluble vitamins	High performance liquid chromatography (Fellman et al., 1992)
Fatty acid profile	Gas chromatography (Christopherson and Glass, 1969)
Cholesterol	Gas chromatography (Smuts et al., 1992)

2.5. Statistical analyses

Nutrient data obtained from the analyses were entered on a spreadsheet using Microsoft Excel (2000). Data was statistically analysed by the ARC-Biometry Unit using GenStat for Windows (2003). The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (whole plots) and treatment (raw and cooked sub-plots), as well as the cut-by-treatment interaction was tested at the 5% level of significance ($p \leqslant 0.05$). If a main effect was significant, the Fishers' protected *t*-test with Least Significant Difference (LSD) was applied, to determine the direction of the differences between mean values (Snedecor and Cochran, 1980).

3. Results and discussion

The majority of the population in most developing countries consumes meat (and meat products) that significantly contributes to nutrient intake for most individuals. Meat provides the following nutrients, namely, fats which provide energy and contain essential fatty acids, minerals such as iron and zinc in a readily-digestible form, vitamins, particularly vitamin B_{12} and a range of amino acids essential for growth and development in the human body (Enser, 2000).

3.1. Raw vs. cooked lamb

The nutrient values of cooked lamb are more useful to the consumers than raw values. The raw values (Table 3) provide baseline information that could be used to evaluate production and marketing effects on nutrient composition. Cooked values, on the other hand, provide information on what is consumed. The differences in the amount of nutrients between raw and cooked meat cuts can be used to calculate nutrient retention. The mean values and standard deviations of this study for proximate analysis, minerals, certain water-soluble vitamins, cholesterol and fatty acids in a composite of raw and cooked meat (100 g edible portion) from three retail cuts of South African lamb (A2, ±7% SCF), are presented in Table 3, Table 4 and Table 5.

Table 3.

Mean values of the nutrient composition for raw and cooked, expressed 100 g edible portion of lean lamb (±7% SCF)[a]

100 g edible portion of lean lamb (±7% SCF) (*n*=18)					
Nutrients analysed	**Unit**	***p*-value**	**SEM[b]**	**Raw**	**Cooked**
Proximate analysis					
Moisture	g	<0.001	0.395	71.5	65.4
Protein (*N*×6.25)	g	<0.001	0.406	18.3	25.1
Fat	g	0.217	0.306	9.01	8.44
Ash	g	<0.001	0.287	2.88	1.07
Food energy (calculated)	kJ	<0.001	14.4	644	745
Minerals					
Magnesium (Mg)	mg	0.405	1.261	20.1	21.7
Potassium (K)	mg	0.852	62.6	291	298

100 g edible portion of lean lamb (±7% SCF) (*n*=18)					
Nutrients analysed	**Unit**	***p*-value**	**SEM[b]**	**Raw**	**Cooked**
Sodium (Na)	mg	0.302	7.90	83.4	71.3
Zinc (Zn)	mg	0.196	0.275	2.25	1.72
Iron (Fe)	mg	0.260	0.198	0.96	0.63
Vitamins					
Thiamin (B_1)	mg	0.017	0.015	0.10	0.04
Riboflavin (B_2)	mg	0.102	0.013	0.09	0.05
Niacin (B_3)	mg	0.869	0.248	1.47	1.42
Pyridoxine (B_6)	mg	0.003	0.054	0.40	0.12
Cyanocobalamin(B_{12})	µg	0.003	0.493	3.54	0.93
Lipids[c]					
Saturated fatty acids					
14:0	g	0.297	0.038	0.57	0.50
16:0	g	0.111	0.086	2.22	1.99
18:0	g	0.002	0.048	1.46	1.07
20:0	g	0.137	0.002	0.02	0.02
Monounsaturated fatty acids					
16:1	g	0.983	0.009	0.19	0.19
18:1n9t	g	0.009	0.017	0.31	0.21
18:1n9c	g	0.001	0.050	3.12	2.65
Polyunsaturated fatty acids					
18:2n6t	g	0.215	0.003	0.02	0.02
18:2n6c	g	0.233	0.014	0.25	0.22
Cholesterol	mg	0.001	4.15	62.8	87.7

p-value: *F*-probability to test for significant differences between composite samples (cuts).

The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (n=12 whole [plots) and treatment (n=18 raw and cooked sub-plots), as well as the cut-by-treatment interaction (n=6) was tested for the 5% level of significance ($p \leqslant 0.05$).

[a] Except for B vitamins, the modes of expression used are according to Greenfield and Southgate (2003).

[b] SEM: standard error of means.

[c] Lipids: fatty acids: represent total fatty acids including free fatty acids.

Table 4.

Mean values of the nutrient composition of three raw and three cooked cut, expressed per 100 g edible portion of lean lamb (±7% SCF)[a]

100 g edible portion of raw and cooked lean lamb (±7% SCF)											
Nutrients analysed	**Unit**	**Raw cuts (*n*=12)**					**Cooked cuts (*n*=12)**				
		***p*-value**	**SEM[b]**	**Shoulder**	**Loin**	**Leg**	***p*-value**	**SEM[b]**	**Shoulder**	**Loin**	**Leg**
Proximate analysis											
Moisture	g	0.012	0.741	70.8[a]	70.1[a]	73.7[b]	<0.001	0.478	66.8[b]	63.5[a]	66.0[b]
Protein (N×6.25)	g	0.346	0.638	18.0	17.8	19.0	<0.001	0.541	23.1[a]	27.8[b]	24.5[a]
Fat	g	0.003	0.814	9.63[a]	11.3[a]	6.15[b]	0.018	0.515	9.86[a]	7.80[b]	7.67[b]
Ash	g	0.918	0.711	2.93	2.65	3.06	<0.001	0.016	0.95[a]	1.20[c]	1.05[b]
Food energy (calculated)	kJ	0.014	33.9	662.0[a]	718[a]	552[b]	0.438	20.4	757	755	722
Minerals											
Magnesium (Mg)	mg	0.076	3.01	13.9	22.7	23.8	<0.001	0.674	17.7[a]	24.2[b]	22.9[b]
Potassium (k)	mg	0.134	51.7	201.	323	351	<0.001	7.51	261[a]	331[c]	303[b]
Sodium (Na)	mg	0.495	19.1	68.0	101	82	<0.001	1.528	68.9[b]	83.3[c]	61.9[a]
Zinc (Zn)	mg	0.512	0.474	1.99	2.05	2.71	0.208	0.357	1.24	2.20	1.71

100 g edible portion of raw and cooked lean lamb (±7% SCF)											
Nutrients analysed	**Unit**	**Raw cuts (*n*=12)**					**Cooked cuts (*n*=12)**				
		***p*-value**	**SEM[b]**	**Shoulder**	**Loin**	**Leg**	***p*-value**	**SEM[b]**	**Shoulder**	**Loin**	**Leg**
Iron (Fe)	mg	0.397	0.197	0.75	0.99	1.14	0.227	0.439	—	0.62	1.20
Vitamins											
Thiamin (B_1)	mg	0.822	0.021	0.11	0.09	0.10	0.740	0.030	0.03	0.04	0.06
Riboflavin (B_2)	mg	0.954	0.027	0.09	0.08	0.09	0.535	0.018	0.04	0.07	0.05
Niacin (B_3)	mg	0.525	0.479	1.70	1.02	1.71	0.736	0.342	1.37	1.25	1.63
Pyridoxine (B_6)	mg	0.099	0.122	0.26	0.32	0.64	0.716	0.030	0.12	0.13	0.10
Cyanocobalamin (B_{12})	µg	0.803	1.085	4.02	3.61	3.00	0.697	0.188	0.8	0.2	1.1
Lipids[c]											
Saturated fatty acids											
14:0	g	0.111	0.095	0.62	0.69	0.39	0.694	0.066	0.50	0.47	0.42
16:0	g	0.010	0.238	2.50[a]	2.67[a]	1.50[b]	0.562	0.120	2.06	1.97	1.86
18:0	g	<0.001	0.132	1.64[a]	1.86[a]	0.88[b]	0.329	0.101	1.10	1.08	1.30
20:0	g	0.120	0.006	0.03	0.03	0.01	0.045	0.005	0.02	0.01	0.02
Monounsaturated fatty acids											
16:1	g	0.152	0.028	0.21	0.21	0.14	0.113	0.009	0.20	0.18	0.16
18:1n9t	g	0.061	0.061	0.33	0.42	0.19	0.907	0.048	0.23	0.24	0.21
18:1n9c	g	<0.001	0.206	3.53[a]	3.70[a]	2.14[b]	0.294	0.102	2.88	2.63	2.71
Polyunsaturated fatty acids											
18:2n6t	G	0.607	0.005	0.03	0.02	0.02	0.886	0.005	0.02	0.02	0.02
18:2n6c	G	0.018	0.029	0.28[a]	0.29[a]	0.17[b]	0.891	0.034	0.24	0.22	0.24
Cholesterol	Mg	0.966	6.09	64.0	61.8	62.7	0.732	6.23	85.0	86.3	91.7

— Unreliable values omitted, currently being re-analysed.

p-value: *F*-probability to test for significant differences between composite samples.

The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (*n*=12 whole plots) and treatment (*n*=18 raw and cooked sub-plots), as well as the cut-by-treatment interaction (*n*=6) was tested at the 5% level of significance ($p \leqslant 0.05$). Means with different letters (a, b or c) are significant different.

[a] Except for B vitamins, the modes of expression used are according to Greenfield and Southgate (2003).

[b] SEM: standard error of means.

[c] Lipids: fatty acids: represent total fatty acids including free fatty acids.

Table 5.

Mean values of the nutrient composition for the interaction between raw and cooked cut, expressed per 100 g edible portion of lean lamb (±7% SCF)[a]

Nutrients analysed	**Unit**	***p*-value**	**SEM[b]**	**100 g edible portion of LEAN Lamb (±7% SCF)**					
				Raw (*n*=6)			**Cooked (*n*=6)**		
				Shoulder	**Loin**	**Leg**	**Shoulder**	**Loin**	**Leg**
Proximate analysis									
Moisture	g	0.054	0.624	70.8	70.1	73.7	66.8	63.5	66.0
Protein (N×6.25)	g	0.007	0.591	18.0[a]	17.8[a]	19.0[a]	23.1[b]	27.8[c]	24.5[b]
Fat	g	0.007	0.681	9.63[b]	11.25[b]	6.15[a]	9.86[b]	7.80[a]	7.67[a]
Ash	g	0.824	0.503	2.93	2.65	3.06	0.95	1.19	1.05
Food energy (calculated)	kJ	0.059	28.0	662	718	552	757	755	723
Minerals									
Magnesium (Mg)	mg	0.545	2.182	13.9	22.7	23.8	18.0	24.2	22.9
Potassium (K)	mg	0.340	36.9	201	323	351	261	330	303
Sodium (Na)	mg	0.716	13.53	67.9	100.7	81.6	68.9	83.3	61.8
Zinc (Zn)	mg	0.470	0.419	1.99	2.05	2.71	1.24	2.20	1.71
Iron (Fe)	mg	0.564	0.340	0.75	0.99	1.14	—	0.62	1.20

Nutrients analysed	**Unit**	***p*-value**	**SEM[b]**	**100 g edible portion of LEAN Lamb (±7% SCF)**					
				Raw (*n*=6)			**Cooked (*n*=6)**		
				Shoulder	**Loin**	**Leg**	**Shoulder**	**Loin**	**Leg**
Vitamins									
Thiamin (B_1)	mg	0.682	0.026	0.11	0.09	0.10	0.03	0.04	0.06
Riboflavin (B_2)	mg	0.700	0.023	0.09	0.08	0.09	0.04	0.07	0.05
Niacin (B_3)	mg	0.807	0.416	1.70	1.02	1.71	1.37	1.25	1.63
Pyridoxine (B_6)	mg	0.101	0.089	0.26	0.32	0.64	0.12	0.13	0.10
Cyanocobalamin(B_{12})	µg	0.768	0.779	4.02	3.61	3.00	0.83	0.91	1.05
Lipids[c]									
Saturated fatty acids									
14:0	g	0.093	0.097	0.62	0.69	0.39	0.59	0.42	0.50
16:0	g	0.020	0.236	2.50[b]	2.67[b]	1.50[a]	2.05[a]	1.92[a]	2.00[a]
18:0	g	0.001	0.140	1.64[b]	1.86[b]	0.88[a]	0.78[a]	1.15[a]	1.27[b]
20:0	g	0.034	0.006	0.03[a]	0.03[a]	0.01[b]	0.01[b]	0.02[b]	0.03[a]
Monounsaturated fatty acids									
16:1	g	0.100	0.026	0.21	0.21	0.14	0.22	0.17	0.18
18:1n9t	g	0.076	0.057	0.33	0.42	0.19	0.22	0.01	0.18
18:1n9c	g	<0.001	0.200	3.53[c]	3.70[c]	2.14[a]	2.60[b]	2.63[b]	2.70[b]
Polyunsaturated fatty acids									
18:2n6t	g	0.567	0.005	0.03	0.02	0.02	0.02	0.02	0.02
18:2n6c	g	0.069	0.033	0.28	0.29	0.17	0.20	0.24	0.23
Cholesterol	mg	0.857	6.26	64	62	63	85	86	92

— Unreliable values omitted, currently being re-analysed.

p-value: *F*-probability to test for significant differences between samples.

The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (*n*=12—whole plots) and treatment (n=18 raw and cooked sub-plots), as well as the cut-by-treatment interaction (n=6) was tested at the 5% level of significance ($p \leqslant 0.05$). Means with different letters (a, b or c) are significantly different.

[a] Except for B vitamins, the modes of expression used are according to Greenfield and Southgate (2003).

[b] SEM: standard error of means.

[c] Lipids: fatty acids: represent total fatty acids including free fatty acids.

3.2. Raw cuts

The nutrient components exhibiting the greatest differences between the three raw cuts, were moisture, total fat, energy, C16:0 and C18:0 saturated fatty acids, C18:1n9c monounsaturated fatty acid and C18:2n6c polyunsaturated fatty acid. According to the results presented in Table 4, the leg cut differed significantly from the shoulder and loin cuts for moisture, fat and energy. The moisture content of the leg cut was significantly higher than the shoulder and the loin. Of the three cuts, the leg had significantly less fat when compared to the shoulder and the loin cut which contained the highest fat value. A study done by Hoke et al. (1999), observed the same trend in that an inverse relationship existed between moisture and fat content. In their study the highest fat and lowest moisture content was found to be in the raw lean rib and blade cuts. The loin also had the highest energy value of the three cuts, followed by the shoulder cut and then the leg with the lowest energy value. The same was found for the fatty acid profiles, where the leg cut contained the lowest fatty acid content of the three cuts, i.e. C16:0 (1.50 g/100 g), C18:0 (0.88 g/100 g) saturated fatty acids, C18:1n9c (2.14 g/100 g) monounsaturated fatty acid and C18:2n6c (0.17 g/100 g) polyunsaturated fatty acid. Maturity of animals influences the meat fatty acid composition. Ono et al. (1984), studied lambs from two age groups and found that lambs from younger animals had higher amounts of some of the saturated fatty acids, and a higher polyunsaturated/saturated fatty acid ratio than those of older animals.

3.3. Cooked cuts

The only significant differences between the cooked cuts (Table 4) were for the moisture, protein, fat, as well as for three minerals (magnesium, potassium and sodium). As expected, moisture losses due to cooking resulted in an increase in the protein and cholesterol concentration. The shoulder and leg had significantly more moisture than the loin cut. According to Lawrie (1998) it is feasible that significant differences may exist between specific muscle locations in the carcass or that breed and age has an effect. The essential amino acids may also differ at different parts of the animal (Lawrie, 1998). The loin cut (27.79 g/100 g) had significantly (p<0.001) more protein when compared to the leg (24.46 g/100 g) and shoulder cuts (23.05 g/100 g). As expected, the shoulder had significantly more fat than the loin and leg cuts. A significant difference was found for ash content, with the loin cut having the highest ash content, followed by the shoulder cut.

Except for sodium, the cooked shoulder cut had the lowest mineral content of the three cuts, and the loin cut had the highest mineral content except for iron. The shoulder contained significantly less magnesium when compared to the loin and the leg. The loin had significantly more potassium with the shoulder the least. The leg cut had significantly lower sodium content, when compared to the loin cut. The loin cut had the highest zinc content, although not significantly, when compared to the leg and the shoulder. These results contrasted the findings of the study by Ono et al. (1984), where the blade chop (shoulder cut) showed the highest value for zinc and the loin chop the lowest.

There were no significant differences in the nutrient values for the vitamins and fatty acids and cholesterol when comparing the three cooked cuts.

3.4. Raw vs. cooked cuts

Red meat contains an array of micronutrients, which are required for general heath and well-being with some being in substantial amounts. The nutrients showing the greatest differences between the treatments, were protein, total fat, as well as the C16:0, C18:0 and C20:0 saturated fatty acid and C18:1n9c monounsaturated fatty acid. As expected, moisture losses due to cooking resulted in an increase in the protein and cholesterol concentration. The present study found that the protein value (Table 5) was significantly higher in the cooked lamb shoulder, loin and leg cuts when compared to the raw shoulder, loin and leg cuts. Furthermore, the cooked loin cut contained the most protein (27.79 g/100 g edible portion) of the three cooked cuts. The total fat content ranged from 6.15 g/100 g in the raw leg and 11.25 g/100 g in the raw shoulder to between 7.67 g/100 g in the cooked leg and 9.86 g/100 g in the cooked shoulder cut.

In this study the iron content differed, although not significantly, between the raw and cooked samples. Iron content decreased in the cooked shoulder and loin cuts but showed an increase in the cooked leg cut. The raw shoulder cut had 0.75 mg iron/100 g. The same result was found for the raw loin (0.99 mg iron/100 g) when compared to the cooked loin cut (0.62 mg iron/100 g). However, the opposite was found for the cooked leg cut, where the raw leg contained 1.14 mg iron/100 g iron compared to 1.20 mg/100 g iron in the cooked cut. Similar results were found by Lombardi-Boccia et al. (2002), where cooking of lamb cuts showed an increase in the iron content between raw and cooked samples. Furthermore, when iron values for raw lean lamb are compared with that of lean beef (11% fat) (Schönfeldt et al., 1996), the raw loin lamb cuts analysed had a higher iron content than that of beef loin (0.99 mg/100 g (lamb, loin) vs. 0.63 mg/100 g (A age beef loin with 11% fat). When cooked, the opposite was found in that cooked beef loin, contained more iron (1.94 mg) per 100 g gram portion than cooked loin (0.62 mg/100 g edible portion) from lamb (Schönfeldt et al 1996). Kruger et al. (2003), emphasised that red meats are the richest source of highly available iron in the diet because it occurs in the most bio-available form, namely haem iron, which is only found in food from animal origin. Lombardi-Boccia et al. (2005), also states that meat (animal products) has the highest bioavailability of iron in the form of haem iron.

The cooked shoulder cut contained the least vitamin B_1, B_2 and B_{12} of the three cooked cuts, the cooked loin cut had the least vitamin B_3 and the cooked leg the least vitamin B_6. The vitamin content for the selected B vitamins of the three cooked lamb cuts were lower, although not significantly, than that of the raw cuts. The cooked shoulder cut, except for vitamin B_3 and B_6, contained the least vitamin B_1, B_2 and vitamin B_{12} (0.8 μg/100 g), while the cooked loin cut contained the least vitamin B_3 (1.25 mg/100 g) and the cooked leg cut, the least vitamin B_6 (0.10 mg/100 g). This could be attributed to the fact that cooking influences the variability of water soluble vitamins in meat due to instability to heat or light and liquid (Lombardi-Boccia et al., 2005). However, when compared to other meat products, it is clear that lamb is a good source of the B vitamins, especially vitamin B_{12}, as supported by Badiani et al. (1998).

Cooking of the three cuts had a concentrating effect on all the nutrients, due to the associated decrease in moisture content during cooking. The only exception was for iron, which decreased in two cuts, namely the shoulder and loin cuts with increased iron content in the leg cut. These results are similar to those reported by Purchas et al. (2004), where a large proportion of the haem iron in beef semitendinosus muscle decreased during cooking.

The cooked shoulder and loin cuts mainly contained significantly less fatty acid than raw cuts while the cooked leg cut contained significantly more of the C14:0, C16:0 and C20:0 saturated fatty acids than that of the raw cut. The cholesterol content for all three cooked lamb cuts was higher than that of the raw cuts, with the shoulder cut containing the highest cholesterol. The cooked shoulder cut had the highest SFA (C14:0–0.59 g/100 g and C16:0–2.05 g/100 g) content except for C18:0 that was the lowest (0.78 g/100 g) within the three samples. The same was found for the MUFA. The shoulder contained the highest C16:1 and C18:1n9t fatty acids with the least C18:1n9c MUFA as well as PUFA C18:2n6t and C18:2n6c. According to Lawrie (1998) it is feasible that significant differences may exist between specific muscle locations in the carcass. However, research in the UK revealed that in general, muscle from cattle, sheep and pigs is a valuable source of polyunsaturated fatty acids in the diet (Lawrie, 1998).

3.5. Recommended dietary allowances

The RDA for males, aged 25–30 (Whitney and Rolfes, 2002) were used as a reference point to evaluate the possible nutrient contribution of lamb, as determined during this study. The RDA provides a benchmark for estimating nutrient needs of healthy people which should be met by the consumption of a variety of nutrient rich food (Gericke, 2003). Three of the nutrients in cooked South African lamb provide more than a third of the RDA's for males aged 25–30 per 100 g edible portion (Table 6). A cooked shoulder, loin and leg lamb cuts provide on average 39% protein, 37% potassium and 38% vitamin B_{12} of RDA for this group of males. Energy from a 100 g portion provides 6.12% of the RDA. Lower levels of nutrients are included in the list namely vitamin B_3 provides 11%, zinc 11%, vitamin B_6 6%. iron 6%, vitamin B_2 4%, and vitamin B_1 that represent 3% of the RDA.

Table 6.

Contribution of 100 g of soft tissue from three cuts of cooked lamb (±7% SCF) to the nutrient requirements (RDA values) of males, age 25–50 years

Contribution of 100 g edible portion lean lamb (±7% SCF) to the RDA males 25–50 years									
Nutrients	**Unit**	**RDA males 25–50[a]**	**Average % contribution**	**Shoulder**	**Shoulder% contribution**	**Loin**	**Loin% contribution**	**Leg**	**Leg% contribution**
Proximate analysis									
Moisture	g	—	—	66.8	—	63.49	—	66.03	—
Protein (*N*×6.25)	g	63	39.8	23.1	36.6	27.8	44.1	24.5	38.8
Fat	g	—	—	9.86	—	7.80	—	7.67	—
Ash	g	—	—	0.95	—	1.19	—	1.05	—
Food energy (calculated)	kJ	12 180	6.12	757	6.22	755	6.20	723	5.94
Minerals									
Magnesium (Mg)	mg	420	—	18.0	—	24.2	—	22.9	—
Potassium (K)	mg	800	37.3	261	32.6	330	41.25	303	37.9
Sodium (Na)	mg	—	—	68.9	—	83.3	—	61.8	—
Zinc (Zn)	mg	15	11.4	1.24	8.27	2.20	14.66	1.71	11.4
Iron (Fe)	mg	10	6.09	—	—	0.62	6.20	1.20	12.0

Contribution of 100 g edible portion lean lamb (±7% SCF) to the RDA males 25–50 years									
Nutrients	**Unit**	**RDA males 25–50[a]**	**Average % contribution**	**Shoulder**	**Shoulder% contribution**	**Loin**	**Loin% contribution**	**Leg**	**Leg% contribution**
Vitamins									
Thiamin (B_1)	mg	1.2	3.47	0.03	2.08	0.04	3.50	0.06	4.83
Riboflavin (B_2)	mg	1.3	4.15	0.04	3.08	0.07	5.38	0.05	4.00
Niacin (B_3)	mg	16	11.7	1.37	8.56	1.25	7.81	1.63	10.2
Pyridoxine (B_6)	mg	1.7	6.80	0.12	6.94	0.132	7.76	0.10	5.71
Cyanocobalamin(B_{12})	µg	2.4	38.8	0.83	34.6	0.91	37.9	1.05	43.8

[a] Whitney and Rolfes (2002), RDA for males 25–50 years.

3.6. Contribution of 100 g of cooked lamb to the nutrient requirements of males

When the nutrient content of lean lamb (±7% SCF) is compared to that of beef, chicken and pork, the different species contained similar amounts of protein (25.01–30.9 g/100 g), and also provides all the essential amino acids in proportions that meet nutrient requirements with cooked beef fillet (A age, 11% fat) being the richer source of iron (3.32 mg/100 g), zinc (4.20 mg/100 g) and vitamin B_{12} (2.25 µg/100 g) (Schönfeldt et al., 1996). According to Lawrie (1998), with respect to species differences, the high content of iron in cooked beef reflects the greater concentration of myoglobin in this species than in lamb or pork. The lean loin cut from lamb (±7% SCF) had the lowest iron content (0.62 mg/100 g) and cooked white meat of chicken (42 days old) the lowest vitamin B_{12} (0.23 mg/100 g) content according to Schönfeldt et al. (1998).

3.7. Nutrient density

Nutrient-dense foods are important sources of many essential nutrients including protein, iron, zinc, some vitamins and fatty acids. According to Whitney and Rolfes (2002), nutrient density is a measure of the nutrients a foodstuff provides relative to the energy it provides. The more nutrients and the fewer kiloJoules, the higher the nutrient density. The nutrient density of a food for a specific nutrient is calculated as follows: The nutrient in 100 g food×the RDA for energy divided by the energy in 100 g food. For example, to calculate the nutrient density of iron in 100 g cooked deboned meat (iron 2.35 g, energy: 1097 kJ) in the diet of males 25–50 years (RDA for iron: 10 mg and energy: 12 180 kJ)

$$(2.35\ \text{mg}/1097\ \text{kJ}) \times (12180\ \text{kJ}/10\ \text{mg}) = 2.61.$$

A value exceeding 1 indicates a good source of that nutrient. In Table 7, the majority of the values are above 1, confirming that three of the cooked lamb cuts, supply significant quantities of a range of protein, iron, zinc and vitamin B_{12} for a limited amount of energy.

Table 7.

Nutrient density of 100 g cooked, deboned South African lean lamb cuts (±7% SCF)

Nutrients	**100 g edible portion of cooked lean lamb cuts (±7% SCF)**		
	Loin	**Leg**	**Shoulder**
Protein	7.11	6.54	5.88
Iron	1.00	2.02	0.09
Zinc	2.36	1.92	1.33
Vitamin B_{12}	6.11	7.37	5.56

Nutrient density=Value ⩾1.00: good source (Van Heerden, 2005).

4. Conclusions

It is evident from this study that lamb provides a variety of valuable nutrients required by human consumers. Another positive attribute of South African lamb is that the protein and mineral content increase during cooking due to moisture loss and that the iron (although it was found to be the lowest in this study), is 3–5 times more readily available than iron from plant foods.

Meat from the lean lamb (±7% SCF) can be regarded as an important dietary source of the B vitamins, although some may be lost due to leaching during the cooking process. Lamb is undoubtedly an excellent source of nutrients that are required for good health. The results showed that there is variation in the micronutrient content between raw and cooked treatments of the three different lamb cuts analysed especially for the proximate analyses values and the minerals of cooked cuts. Cooking affected mainly the moisture, protein, fat, ash and energy values, which were higher in the cooked meat cuts as well differed significantly between the cooked cuts. There was no significant difference in the iron and zinc between the cooked cuts. Furthermore, results showed differences in both trace elements and B vitamins among different cuts, although the differences were not statistically significant.

Lamb (±7% SCF) makes a valuable contribution to the RDA for males, aged 25–50 years, with regard to the protein, potassium, zinc, vitamin B_{12} and B_3 when included as part of a balanced meal plan. Therefore, as recommended in healthy eating advice around the world, lean meat especially lean lamb, consumed in moderation should be promoted as part of a healthy balanced diet.

Consuming nutrient-dense foods, as part of a balanced diet that includes the recommended servings, can help consumers achieve good health. Comparing data with other countries show that the use of non-local data sources can produce differences in the assessment of the nutrient composition and may cause conflicting interpretation of dietary intake. Therefore, accurate local data on nutrient composition is essential for assessing dietary intakes, determining the relationship between dietary intake and disease occurrence as well as for communicating nutrient information to the consumers. This study contributes valuable data to the nutrient profile of red meat, especially South African lamb. However, this is data on A2 class only (±7% SCF), and more work is required on the rest of the classification system of South African lamb to ensure a complete data set.

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