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THE NUTRIENT COMPOSITION OF SOUTH AFRICAN LAMB (A2 CLASS)

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"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

In this chapter the style and layout, as prescribed by the Journal in which the article will be published namely, Journal of Food Composition and Analysis, has been followed.

ABSTRACT

Dorper and Mutton 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.

Key Words: Nutrient composition, South African lamb, leg, loin, shoulder cuts.

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 tables are derived from South African foodstuffs (SAFCoD, 2000). The current data on mutton (lamb and sheep) that appear in the MRC's food composition tables of 1999 are derived from the United States Department of Agriculture (USDA) database (Sayed, Frans & Schönfeldt, 1999:51, 65).

In different countries the nutrient content and carcass composition of the sheep population may vary due to differences in preferred age and fatness classes, breeds, carcass cutting techniques and production systems. In addition, the differences in climate, soil content and water composition of the various regions, furthermore, affect 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, 2003:69). Different age groups and fat codes of the animals in various countries make the interpretation of the results difficult as the composition of the carcasses has a direct influence on the nutrient content thereof (Schönfeldt, 1998:4). Therefore, it is important that different countries have their own food composition tables for meat cuts (and meat products) such as lamb, mutton, beef and pork.

The Medical Research Council (MRC) is responsible for compiling South African food composition tables (Langenhoven, Kruger, Gouws & Faber, 1993:1). These tables are used in dietary surveys, nutritional intervention research, nutrition education, consumer information to name but a few. The Research Institute for Nutritional Diseases (NRIND) issued the first food composition tables in 1991 (Langenhoven, Kruger, Gouws & Faber, 1993:1). However, these tables did not include unique values for South African meat products, but consist of data obtained mainly from American and English composition tables and this is not readily applicable to the South African context.

The 1999 MRC Food Composition Tables of South Africa were revised and the database has been increased with local South African data for vegetables, beef, chicken, fruit and dairy to a total of 41 % (Langenhoven *et al.,* 1993:1). The nutrient content of 59 % of the food consumed daily in South Africa is largely estimated or extrapolated from foreign data (including the data on South African lamb) (Codjia, 2000:41). According to Cobiac, Droulez, Leppard and Lewis (2003:133) accurate nutrient composition data are essential in communicating nutrition information to consumers and therefore it was a priority to analyse the nutrient composition of South African lamb.

Table 1 provides a comparison and variation of the macro- and micronutrient content of lean lamb when different databases are used. It illustrates how the use of different food composition tables may cause conflicting interpretation of dietary intake data.

The Australian values are, on average, the most different from the other countries and this could be attributed to the fact that they are trimming their meat cuts to a specific fat thickness. The greatest differences in values observed between countries were for protein, total fat, ash, energy, some minerals as well as some of the fatty acids. The nutrient content of meat is influenced by the amount of fat it contains, and as fat content (and fatty acids) increases, the protein content (and amino acids) decreases, with corresponding increased energy content.

Table 1:

Nutrient values in lamb per 100 g cooked edible portion of selected countries

Nutrients	**Unit**	**South Africa**[1]	**USA**[2]	**UK**[3]	**Australia**[4]	**New Zealand**[5]
		Cooked Leg & shank	**Cooked Leg-roasted, lean & fat**	**Cooked Lamb-roast**	**Cooked Fresh leg & shank**	**Cooked leg (shank & sirloin)**
		Lean	**Lean & fat**	**90 % meat**	**Trimmed to ±4 mm fat**	**12 % separable fat**
		100 g	100 g	100 g	100 g	100 g
Proximate analysis:						
Moisture	g	57.5	67.0	58.70	59.2	63.92
Protein (Nx6.25)	g	25.6	25.8	24.30	29.3	27.68
Fat	g	16.5	16.5	13.30	11.9	7.01
Ash	g	-	-	-	1.10	1.52
Food energy (calculated)	kJ	1046	1095	905	937	757
Minerals:						
Magnesium (Mg)	mg	24	-	24	19	21
Potassium (K)	mg	313	312	350	290	183
Sodium (Na)	mg	66	66	61	66	45
Zinc (Zn)	mg	4.4	-	4.5	4.5	4.0
Iron (Fe)	mg	2.0	2.0	1.9	2.4	2.2
Vitamins:						
Thiamin (B_1)	mg	0.1	-	0.15	0.06	0.12
Riboflavin (B_2)	mg	0.27	0.27	0.27	0.25	0.50
Niacin (B_3)	mg	6.6	6.6	4.5	4.5	7.51
Pyridoxine (B_6)	mg	0.5	-	0.22	-	0.14
Cyanocobalamin (B_{12})	μg	2.6	-	4	-	2.63
Lipids:						
SFA	g	0.8	6.9	6.1	6.1	3.05
MUFA	g	3.5	6.9	5.3	4.3	2.75
PUFA	g	0.36	1.2	0.7	0.2	0.41
Cholesterol	mg	93	93	98	109	100

1 Sayed, Frans and Schönfeldt (1999)
2 Gebhardt and Thomas (2002:58)
3 Chan, Brown, Church and Buss (1996:56-59)
4 Lewis, Milligan and Hurt (1995, Vol. 1)
5 United Stated Department of Agriculture (1989:107)
\- Value not available

In South Africa, the current food composition data indicates that lamb meat contains 16 g fat per 100 g edible portion and this is the same as the USDA's. The United Kingdom followed with 13 g fat per 100 g portion and Australia containing 12 g and New Zealand, 7 g fat per 100 g. The higher the fat content of a meat cut, the higher the energy content. The variation in the total fat content could be attributed to the proportion of fat and lean meat as suggested by different slaughter masses; natural variation in fat content between animals, cutting up and trimming techniques and visible subcutaneous and intermuscular fat included in cuts such as loin chops.

The moisture loss for the UK, Australia and South Africa was lower when compared to the USA and New Zealand. These differences could be due to nutrient retention with different cooking methods (indicated in tables as "cooked" and "cooked – roasted").

Red meat is the most significant source of protein, providing all the essential amino acids. From the current MRC food composition tables being used, South African lamb provides over 25 g protein per 100 g edible portion. This is 50 % of the RDA for protein for females 25 – 50 years old (Whitney & Rolfes, 2002:1). The protein content (Table 3) per 100 g edible portion was the highest for Australia (29 g / 100 g) followed by New Zealand with 28 g / 100 g and the UK only containing 24 g / 100 g on average.

Differences in iron content reflect the concentration of myoglobin in the different species. According to the current MRC food composition tables, cooked SA lamb provides 14 % (2.2 g / 100 g) iron of the RDA for females 25-50 years old. Iron content of meat is positively correlated with the age of the animal (Lawrie, 1998:62) and therefore the iron content suggests that SA lamb is, on average, slaughtered at a younger age than those of the United States of America and Britain and substantially younger than those from Australia (2.4 g / 100 g) and New Zealand (2.2 g / 100 g). The contribution of zinc from SA lamb data in the current MRC food composition tables is 36 % (4.4 mg / 100 g) of the RDA for females 25-50 years old.

Food choices may 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, Van der Spuy & Viljoen, 2003:271). Therefore, in order to evaluate a person's food intake according to the Recommended Dietary Allowance (RDA) (Whitney & Rolfes, 2002:1), the nutritional composition of the diet is calculated by making use of food composition databases, either in computerized soft ware 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, 1997:251).

In developing countries, such as in South Africa, nutrient deficiencies are widespread and one of the major health concerns is the poor micronutrient content of the diet. Iron deficiency resulting in anemia, is the most common deficiency in the world that causes ill health. Data from the South African National Food Consumption Survey (Steyn, MacIntyre, Labadarios, Maunder, Swart, Nesamvuni, Gericke, Huskisson, Vorster, & Dannhauser, 2000) showed that children aged 1-9 years had low mean intakes of iron, protein, B-vitamins and minerals such as zinc and iodine. To address these deficiencies the nutrient content of various South African foodstuffs – such as lamb – need to be analysed and explored furthered.

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 such data, as identified in 1987 by the South African Food Composition Data (SAFCoD), the Agricultural Research Council, Livestock Business Division, 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.

MATERIALS AND METHODS

Sampling

The South African classification system (National Department of Agriculture, 1990:9-14) is designed to describe carcasses according to tissue composition and potential eating quality (tenderness). Carcasses are grouped into seven 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, 1990:9-14) an A age class, fat code 2 lamb will 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).

To have lamb meat that represents the South African lamb as purchased by the consumer, carcasses of the A age class and fatness level 2 (± 7 % SCF and with no incisors) were selected from the meat industry. Stratified sampling was used. This is a method where food is classified into strata, taking into account the most important causes of variation. In this project the units of samples were taken from defined strata (subparts / regions, breeds) of the parent population (South African sheep) (Greenfield & Southgate, 2003:70-71) It was done 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 meat samples, incorporated in the study, comprised of the most commonly consumed carcasses in South Africa (Van der Westhuizen, personal communication, 2003), namely Dorper (n = 9) and Mutton Merino (n = 9) wethers. The attributes used were selected based on the fact that sheep are drawn from main production areas to supply the main abattoirs (Table 2). 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 were classified according to the South African classification system by a qualified classifier at the abattoirs. The lambs were slaughtered using standard commercial procedures during four consecutive weeks. Selected carcasses were transported in a refrigerated truck (4 - 6 °C) to the Meat

Industry Centre of the then 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, feet, kidney and kidney fat had been 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 with shank, breast, loin, leg with shank. Three cuts (shoulder, leg and loin), representing the most commonly consumed cuts, taken from both sides, were used to determine the cooked (left side) and raw (right side) nutrient composition. The cuts, from the left sides used for the cooked analysis, were vacuum packed and frozen for two months at - 20 °C until the cooking process commenced. The raw and cooked nutrient data of the three cuts was compared based on the assumption, (Kirton, Barton and Rae, 1962:383-385) that the chemical composition of the two sides is similar or almost identical.

Table 2:

Experimental design for the sampling and nutrient analysis of A age class, fat class 2 South African lamb

<table>
<tr><td colspan="6">18 A - Age class, fat class 2 lamb carcasses – wethers</td></tr>
<tr><td colspan="3">9 Dorper</td><td colspan="3">9 Mutton Merino</td></tr>
<tr><td colspan="2">Ermelo</td><td colspan="2">Kalahari</td><td colspan="2">Karoo</td></tr>
<tr><td colspan="2">3 Mutton Merino
3 Dorper</td><td colspan="2">3 Mutton Merino
3 Dorper</td><td colspan="2">3 Mutton Merino
3 Dorper</td></tr>
<tr><td>6 Right sides
Raw</td><td>6 Left side
Cooked</td><td>6 Right sides
Raw</td><td>6 Left side
Cooked</td><td>6 Right sides
Raw</td><td>6 Left side
Cooked</td></tr>
<tr><td>Composite sample</td><td>Composite sample</td><td>Composite sample</td><td>Composite sample</td><td>Composite sample</td><td>Composite sample</td></tr>
<tr><td>• Macronutrient analysis on meat & fat of 7 cuts
• Micronutrient analysis on meat, & fat of 3 cuts</td><td>• Macro- & micro nutrient analysis on meat, fat of 3 cuts</td><td>• Macronutrient analysis on meat & fat of 7 cuts
• Micronutrient analysis on meat, & fat of 3 cuts</td><td>Macro- & micro nutrient analysis on meat, fat of 3 cuts</td><td>• Macronutrient analysis on meat & fat of 7 cuts
• Micronutrient analysis on meat, & fat of 3 cuts</td><td>Macro- & micro nutrient analysis on meat, fat of 3 cuts</td></tr>
</table>

Sample preparation

In order to comply with the new Draft Regulations relating to the labelling and advertising of foodstuffs, as part of the Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972, (http://www.doh.gov.za/department/dir_foodcontr.html), it was decided 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 through budgeting constraints and is an accepted approach in food composition studies (Greenfield and Southgate, 2003:50).

Right sides

A trained deboning team was responsible for the physical dissection of the 18 raw lamb carcasses that had been weighed prior to being sub divided into primal (seven wholesale) cuts (Table 2). The cuts from the **right** sides (raw) were dissected by knife into three portions namely meat (muscle, intermuscular- + intramuscular fat i.e. fat within the muscle), bone and subcutaneous fat, in an environmentally controlled (10 °C) deboning room. Samples were taken from the fat and meat for the proximate (macronutrients) and micronutrient analysis from the three cuts.

Left sides

All the wholesale cuts from the 18 **left sides** were vacuum packed and frozen until it was needed for cooking and nutrient analysis in the cooked tissues. After two months of freezing, the shoulder, loin and leg cuts (Table 2) were thawed, weighed and cooked (as a whole cut with bone) according to standardized cooking methods (leg and loin cuts - dry heat cooking method, shoulder - moist heat cooking method) in identical Mielé ovens at 160 °C, to an internal temperature of 70 °C, (60 minutes per kilogram for shoulder and leg cuts and 45 minutes per kilogram for the loin cut) measured in the geometrical centre of the cut (American Meat Science Association, 1995:5-8). Dry heat cooking entailed the oven roasting of the meat uncovered meat on a flat open pan, with a rack to keep the meat out of the drip. No water (liquid) is added during cooking). The heat is transferred through the air in oven to the meat. The moist heat cooking method was followed for the shoulder cut that was heated in a covered pan with added water (Charley, 1986:406-409). After cooking, the meat cuts were cooled down and then dissected into three portions namely meat (muscle, intermuscular- + intramuscular fat), bone and subcutaneous fat, in an environmentally controlled (10 °C) deboning room by the team of experienced dissectors.

Preparation of the raw and cooked composite samples

Samples from nine carcasses from two breeds (n=18) were combined into 6 composite samples for each cut for the nutrient analysis. 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 (chemical) analysis, vitamins, minerals, fatty acids and cholesterol). To prepare the composite samples (n=6) the meat and fat, respectively, of all the replications of each of the three raw and cooked cuts were combined and cubed, thoroughly mixed and then minced, firstly through a 5 mm and then through a plate with 3 mm diameter holes. Samples of 300 g meat and separable fat were homogenized with an Ultra Turrax T25 homogenizer after mincing to ensure a proper homogenized sample. These samples were then, depending on the analysis, either placed in glass bottles prior to being frozen, or into aluminium trays covered with a vacuum bag prior to being freeze-dried.

Analyses

The analytical procedures (Table 3) 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). Reference samples form part of the daily routine in these laboratories to assure the quality of results. 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 3:
Methods used for the nutrient analyses of raw and cooked lamb

Analysis	Method
Moisture (water)	Official Method 950.46 AOAC (2005)
Ash	Official Method 920.153 AOAC (2005)
Protein (N)	Official Method 992.15 AOAC (2005) (Dumas combustion method)
Fat	Official Method 960.39 AOAC (2005) (Soxtec ether extraction)
Energy	Calculated (Atwater & Bryant, 1900)
Minerals	Ion Chromatography (IC) sub-contracted laboratory
Water-soluble vitamins	
B_1, B_2	High Performance Liquid Chromatography (HPLC) (Fellman et al.1992)
B_3	Official Method 961.14 AOAC (2005)
B_6	Official Method ALASA 7.2.3
B_{12}	Official Method AOAC 986.23 (2005)
Fatty acid profile	Gas Chromatography (GC) (Christopherson & Glass, 1969)
Cholesterol	Gas Chromatography (GC) (Smuts et al., 1992)

STATISTICAL ANALYSES

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 ($p \leq 0.05$). If a main effect was significant, the Fisher's protected t-test with Least Significant Difference (LSD) was applied, to determine the direction of the differences between mean values (Snedecor, & Cochran, 1980: 234-35).

RESULTS AND DISCUSSION

In Table 4 the mean values of the nutrient composition for raw and cooked 100 g edible portion of South African A2 lamb are discussed. The nutrient values of cooked lamb are more useful to the consumers than raw values (Ono, Berry, Johnson, Russek, Parker, Cahill and Althouse, 1984:1239). The raw values (Table 4) provide base-line 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 actually consumed and according to Ono et al. (1984:1239) the differences in the amount of nutrients between raw and cooked meat cuts can be used to calculate nutrient retention in the cuts. Looking at the differences between raw and cooked South African lamb, the nutrient components (Table 4) exhibiting the greatest differences between the three raw cuts were moisture, total fat, energy, C14:0, C16:0 and C18:0 saturated fatty acids, C18:1n9c monounsaturated fatty acid and C18:2n6c polyunsaturated fatty acid. As expected, moisture losses due to cooking resulted in an increase in the protein, energy and cholesterol concentration. The protein content was significant higher in the cooked meat (25 g / 100 g) when compared to the raw meat (18 g / 100 g). A notable decrease in the water-soluble vitamin content was noted in the cooked meat. Except for magnesium and potassium, all the other minerals decreased with cooking.

Table 4:

Mean values of the nutrient composition for raw and cooked 100 g edible portion of South African A2 lamb

NUTRIENTS ANALYSED	Unit	p-value	SEM	RAW (n=6)	COOKED (n=6)
PROXIMATE ANALYSIS:					
Moisture	g	<0.001	0.395	71.5	65.4
Protein (Nx6.25)	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
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: **Saturated fatty acids (SFA)**					
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(MUFA)					
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 (PUFA)					
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

Raw and cooked data relates to the shoulder, loin and leg cuts only
p-value: F-probability to test for significant differences between composite samples (cuts)
SEM: Standard Error of Means. 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 carcass sides – sub-plots), as well as the cut-by-treatment interaction (n = 6 composite samples) was tested for the 5 % level of significance ($p \leq 0.05$).

According to the results of the three raw and cooked cuts presented in Table 5, the raw leg cut differed significantly from the shoulder and loin cuts for moisture, fat and energy. The moisture content of the raw leg cut was significantly higher than the shoulder and the loin.

Table 5:

Mean values of the nutrient composition of three raw and three cooked cuts per 100 g edible portion of South African A2 lamb

NUTRIENTS ANALYSED		RAW CUTS (n = 12)					COOKED CUTS (n = 12)				
	Unit	**p-value**	**SEM**	**Shoulder**	**Loin**	**Leg**	**p-value**	**SEM**	**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 (Nx6.25)	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^{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
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:											
Saturated fatty acids (SFA)											
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 (MUFA)											
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 (PUFA)											
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

\- Value not available
p-value: F-probability to test for significant differences between composite samples
SEM: Standard Error of Means. 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 ($p \leq 0.05$). Means with different letters (a, b or c) are significant different.

Of the three raw cuts, the leg had significantly less fat when compared to the shoulder and the loin cuts which contained the highest fat value. A study done by Hoke, Buege, Ellefson and Maly, (1999:102, 108) 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. As a result of higher fat the loin had the highest energy value of the three cuts, followed by the shoulder cut and then the leg with the lowest energy value. In addition the same was found for the fatty acid profile, where the raw 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 fatty acid composition of the meat. Ono *et al.* (1984:1237, 1239), 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.

According to the results (Table 5), the only significant differences between the cooked cuts were for the moisture, protein, fat, energy as well as three minerals (magnesium, potassium and sodium). 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 (1998:85, 259) 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, 1998:85, 259). The cooked loin cut (27.8 g / 100 g) had significantly ($p < 0.001$) more protein when compared to the leg (24.5 g / 100 g) and shoulder cuts (23.15 g / 100 g). As expected, the cooked shoulder had significantly more fat than the cooked loin and leg cuts. A significant difference was found for ash content, with the cooked loin cut having the highest ash content, followed by the cooked shoulder cut. Except for sodium, the cooked shoulder cut had the lowest mineral content of the three cooked 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.* (1984:1239) 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.

Red meat contains a wide array of micronutrients which are required for general heath and well-being with some being present in substantial amounts. In Table 6 the mean values of the nutrient composition for the interaction between raw and cooked cuts expressed per 100 g edible portion for South African A2 lamb are shown and the influence of cooking on the nutrients is clear from this table. The nutrients showing the greatest differences between the three cuts for the raw and cooked treatments were protein, total fat, as well as the C16:0, C18:0 and C20:0 saturated fatty acids and C18:1n9c monounsaturated fatty acid. As expected, moisture losses due to cooking resulted in an increase in the protein and cholesterol concentrations. The present study found that the protein value (Table 6) was significantly higher in the cooked lamb

Table 6:

Mean values of the nutrient composition for the interaction between raw and cooked 100 g edible portion for South African A2 lamb

NUTRIENTS ANALYSED				RAW (n=6)			COOKED (n=6)		
	Unit	p-value	SEM	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 (Nx6.25)	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
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:									
Saturated fatty acids (SFA)									
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 (MUFA)									
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 (PUFA)									
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

\- Value not available
p-value: F-probability to test for significant differences between samples
SEM: Standard Error of Means. 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 ($p \leq 0.05$). Means with different letters (a, b or c) are significant different

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. According to Williamson, Foster, StanNer and Buttriss (2005:325), the more fat the meat contains, the higher the energy content.

In this study the iron content differed, although not significantly, between the three raw and cooked samples. Iron content decreased in the cooked loin cuts but showed an increase in the cooked leg cut (no value for cooed shoulder). 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. The increase of mineral content in cooked meat is mainly due to moisture loss (Lawrie 1998:260). Similar results were found by Lombardi-Boccia, Martinez-Dominguez and Aguzzi (2002:1740), 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, Visser, Van Niekerk & Van Heerden, 1996:18, 20), the raw loin lamb cuts had a higher iron content than 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, cooked beef loin, contained more iron (1.94 mg) per 100 g gram portion than cooked lamb loin (0.62 mg / 100 g edible portion) (Schönfeldt, Visser, Van Niekerk & Van Heerden, 1996:18, 20). This could be attributed to the fact that iron is bound in the haemoglobin in red meat and therefore, a concentration effect take place with the more protein present associated with a higher iron content. Kruger, Van der Spuy and Viljoen (2003:344) and Lombardi-Boccia, et al. (2005:39-46), 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. According to Lawrie (1998:260) in respect to species differences the high content of iron in beef reflects the greater concentration of myoglobin in comparison to mutton or pork.

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.,* 2005:40). 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, Nanni, Gatta, Bitossi, Tolomelli and Manfredini (1998:97).

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 iron, an important nutrient in the diet, which decreased in the loin cut and exhibit increased iron content in the leg cut. These results are similar to those reported by Purchas, Rutherfurd, Pearce, Vather and Wilkinson (2004:206), where a large proportion of the haem iron in beef *Semitendinosus* muscle decreased during cooking.

The cooked shoulder and loin cuts (table 6) mainly contained less fatty acids than raw cuts while the cooked leg cut contained 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, although not significantly, than 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) compared to the three samples. The cooked 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 (1998:85, 259) it is feasible that significant differences may exist between the nutrient content of specific muscle locations in the carcass. However, research in the U.K. revealed that in general, muscle from cattle, sheep and pigs is a valuable source of polyunsaturated fatty acids in the diet (Lawrie, 1998:260-267).

Comparison between current study and MRC food composition tables

The results demonstrated that meat varies in its contributions to the diet, mainly due to the sources of the data (Table 7). When comparing the new food composition (lamb) data from the study with the current data included in the South African food composition tales (Sayed, Frans & Schönfeldt, 1999) it is clear that there are large differences in the nutrient composition of lamb between these two sets of data. This clearly illustrates that the use of non-local data sources can produce differences in the assessment of its nutrient composition and may cause conflicting interpretations of dietary intakes. To illustrate these differences the following calculation can be done. The percentage difference of a specific nutrient value between the current study (Table 5) and the MRC food composition tables (value as in Table 1) can be calculated using the following formula: Difference of nutrient value between current study and MRC table value, times 100, divided by the MRC value for the nutrient.
For example: Difference in protein content of the cooked leg cut.

25.6 g – 24.5 g = 1.1 g

$$\frac{1.1 \text{ g} \times 100}{25.6 \text{ g}}$$

= 4.3 % less protein in the current study when compared to that of the MRC tables.

According to Table 7 in the current study, cooked SA lamb (A age class, fat class 2) contains an average of 12.9 g (60.5 %) less total fat and 1.4 g (5.28 %) less protein, resulting in 1891 kJ less per 100 g edible portion energy (71.73 %), if compared to the previous values in the food composition tables are compared. The vitamin and mineral content of the raw and cooked A age class, fat class 2 lamb from the current study is lower except for potassium, in the raw meat, which is 131 mg (81.8 %) more when compared to the values of a 100 g edible portion of lean lamb in the 1999 MRC tables.

Table 7:

Comparison of the nutrient composition for raw and cooked 100 g edible portion of lean lamb between the South African 1999 MRC Food composition tables and the results of the current study on the A2 lamb

		RAW		DIFFER-ENCE BETWEEN STUDIES[3]	COOKED		DIFFER-ENCE BETWEEN STUDIES[3]
NUTRIENTS ANALYSED	**Unit**	**CURRENT STUDY[1]**	**1999 MRC TABLES[2]**		**CURRENT STUDY[1]**	**1999 MRC TABLES[2]**	
PROXIMATE ANALYSIS:							
Moisture	g	71.5	60.7	10.8	65.4	51.4	14
Protein (Nx6.25)	g	18.3	16.9	1.4	25.1	26.5	-1.4
Fat	g	9.01	21.6	-12.59	8.44	21.4	-12.96
Ash	g	2.88	-		1.07	-	
Food energy (calculated)	kJ	644	1087	-443	745	2636	-1891
MINERALS:							
Magnesium (Mg)	mg	20.1	22	-1.9	21.7	24	-2.3
Potassium (K)	mg	291	160	131	298	296	2
Sodium (Na)	mg	83.4	230	-146.6	71.3	72.6	-1.3
Zinc (Zn)	mg	2.25	3.33	-1.08	1.72	4.75	-3.03
Iron (Fe)	mg	0.96	1.6	-0.64	0.63	2.06	-1.43
VITAMINS:							
Thiamin (B_1)	mg	0.10	0.12	-0.02	0.04	0.09	-0.05
Riboflavin (B_2)	mg	0.09	0.22	-0.13	0.05	0.24	-0.19
Niacin (B_3)	mg	1.47	6.1	-4.63	1.42	6.66	-5.24
Pyridoxine (B_6)	mg	0.40	0.13	0.27	0.12	0.13	-0.01
Cyanocobalamin(B_{12})	µg	3.54	2.40	1.14	0.93	2.63	-1.7
LIPIDS: **Saturated fatty acids (SFA)**	g	1.07	2.15	-1.08	0.90	2.08	-1.18
14:0	g	0.57	0.87	-0.3	0.50	0.82	-0.32
16:0	g	2.22	4.75	-2.53	1.99	4.59	-2.6
18:0	g	1.46	2.98	-1.52	1.07	2.89	-1.82
20:0	g	0.02	0.0	0.02	0.02	0.0	0.02
Monounsaturated fatty acids(MUFA)	g	1.18	4.30	-3.12	1.53	4.33	-2.8
16:1	g	0.19	0.63	-0.44	0.19	0.62	-0.43
18:1	g	3.43	7.96	-4.53	2.86	8.04	-7.83
Polyunsaturated fatty acids (PUFA)	g	-	0.33	0.33	-	0.20	0.33
18:2	g	0.27	1.24	-0.97	0.24	1.21	-0.97
Cholesterol	mg	62.8	72	-9.2	87.7	103	-15.3

1 Data from current study (Table 4)
2 Sayed, Frans & Schönfeldt, 1999
3 Difference: Calculated on the difference between the values of the current study (Table 4) and that of the 1999 MRC food composition tables (Sayed, Frans & Schönfeldt, 1999.)
\- Indicates that the current study has less of the particular nutrient than the MRC-tables

Recommended Dietary Allowances

The Recommended Dietary Allowances (RDA) for males, aged 25 - 30 years (Whitney & Rolfes, 2002:1), were used as the 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, 2003:228). Three of the nutrients in cooked South African lamb provide more than a third of the RDA's for males aged 25 - 50 years per 100 g edible portion (Table 8). A 100 g portion of cooked shoulder, loin and leg lamb cuts provide on average 40 % protein, 37 % potassium and 39 % vitamin B_{12} of RDA for this group of males. Energy from a 100 g portion provides 6 % of the RDA. Lower levels of nutrients are included in the list namely vitamin B_3 provides 11.71 %, zinc 11.44 %, vitamin B_6 6.80 %. iron 6.09 %, vitamin B_2 4.15 %, and vitamin B_1 that represent 3.47 % of the RDA.

Table 8:

Contribution of 100 g edible portion of cooked (deboned) meat from three A2 lamb cuts to the nutrient allowances (RDA values) of males, aged 25 – 50 years

NUTRIENTS	UNIT	*RDA MALES 25-50	Shoulder	Shoulder % con-tribution	Loin	Loin % con-tribution	Leg	Leg % con-tribution	Average % con-tribution
PROXIMATE ANALYSIS:									
Moisture	g	-	66.8	-	63.49	-	66.03	-	-
Protein (Nx6.25)	g	63	23.1	36.6	27.8	44.1	24.5	38.8	39.8
Fat	g	-	9.86	-	7.80	-	7.67	-	-
Ash	g	-	0.95	-	1.19	-	1.05	-	-
Food energy (calculated)	kJ	12 180	757	6.22	755	6.20	723	5.94	6.12
MINERALS:									
Magnesium (Mg)	mg	420	18.0	-	24.2	-	22.9	-	-
Potassium (K)	mg	800	261	32.6	330	41.25	303	37.9	37.3
Sodium (Na)	mg	-	68.9	-	83.3	-	61.8	-	-
Zinc (Zn)	mg	15	1.24	8.27	2.20	14.66	1.71	11.4	11.4
Iron (Fe)	mg	10	-	-	0.62	6.20	1.20	12.0	6.09
VITAMINS:									
Thiamin (B_1)	mg	1.2	0.03	2.08	0.04	3.50	0.06	4.83	3.47
Riboflavin (B_2)	mg	1.3	0.04	3.08	0.07	5.38	0.05	4.00	4.15
Niacin (B_3)	mg	16	1.37	8.56	1.25	7.81	1.63	10.2	11.7
Pyridoxine (B_6)	mg	1.7	0.12	6.94	0.132	7.76	0.10	5.71	6.80
Cyanocobalamin (B_{12})	µg	2.4	0.83	34.6	0.91	37.9	1.05	43.8	38.8

* Whitney and Rolfes (2002:1), RDA for males 25-50 years.
\- Value not available

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

When the nutrient content of lean lamb (A2) is compared to that of beef, chicken and pork, the different species contain similar amounts of protein (25.01 – 30.9 g / 100 g) (Sayed, Frans & Schönfeldt, 1999). Lamb also provides all the essential amino acids in proportions that meet basic nutrient requirements. Cooked beef (A age, 4 % fat), however is the richer source of iron (1.99 mg / 100 g), zinc (4.45 mg / 100 g) and vitamin B_{12} (2.26 µg / 100 g) (Schönfeldt, Visser, Van Niekerk, and Van Heerden, 1996:94) compared to lamb. According to Lawrie (1998:260), 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 cooked 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, Van Heerden, Van Niekerk, Visser, and Heinze (1998:27). Lamb contains a range of nutrients that contribute to its important place in a healthy diet.

Nutrient density and the Index of Nutritional Quantity

Nutrient-dense foods are important sources of many essential nutrients including protein, iron, zinc, some vitamins and fatty acids. According to Whitney and Rolfes (2002:32), nutrient density is a measure of the nutrients a foodstuff provides relative to the energy it provides. The nutrient density of a food for a specific nutrient is calculated as follows: For example, to calculate the nutrient density of iron in 100 g cooked deboned meat (iron 2.35 mg, energy: 1097 kJ) in the diet of males 25-50 years (RDA for iron: 10 mg and energy: 12 180 kJ):

$$\frac{2.35\text{ mg}}{1097\text{ kJ}} \times \frac{12180\text{ kJ}}{10\text{ mg}}$$

$$= 2.61$$

A value exceeding 1 indicates a good source of that nutrient. In Table 9, 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. The more nutrients present and the fewer kiloJoules, the higher the nutrient density.

The nutrient density approach recommended nutrient intakes and nutritional composition of foods are expressed in terms of nutrient quantity per 1000 kcal (4200 kJ) by Lee and Nieman (2003:27). On the other hand, the Index of Nutritional Quality (INQ) is a concept where the quantity of a nutrient per 1000 kcal (4200 kJ) in a food is compared with a nutrient standard. To achieve nutrient adequacy on a 1000-kcal to 1200-kcal reducing diet, most foods consumed should have a nutrient density approximately double the 1000-kcal allowance (Lee & Nieman, 2003:27). The INQ of a food is calculated using the following formula: INQ = Amount of nutrient in 1000 kcal (4200 kJ) of food is divided by the allowance of nutrient per 1000 kcal (4200 kJ) of food. For example:
A 100g portion cooked leg provides 723 kJ and 1.20 mg Iron (Table 5) (Lee & Nieman, 2003:27)

$$\frac{4200 \text{ kJ} \times 1.20 \text{ mg iron}}{723 \text{ kJ}}$$

$$= 6.97 \text{ mg iron per } 4200 \text{ kJ}$$

Therefore:

$$\frac{6.97 \text{ mg iron}}{4 \text{ mg}} \text{ per } 4200 \text{ kJ}$$

$$= 1.74$$

It has been proposed that if a food has an INQ of two or more for two nutrients or one or more, for four nutrients, it makes a significant contribution to the total nutrient intake and therefore should be regarded as ”nutritious” (Guthrie & Picciano, 1995:53).

According to the values tabulated in Table 9 the leg, loin and shoulder cuts from South African lamb makes a significant contribution to the total nutrient intake and therefore should be regarded as ”nutritious”. These cuts are rich in Vitamin B_{12} and zinc. Only iron in the loin that is <1 and therefore not adequate, however three of the nutrients (protein, zinc and vitamin B_{12}) are >2 and can be regarded as nutritious. The leg and shoulder cuts each has 2 nutrients (protein and vitamin B_{12}) that are >2, and four nutrients (protein, iron, zinc and vitamin B_{12}) that are >1 and therefore could be regarded as “nutritious” because it makes a significant contribution to the total nutrient intake, even with the iron content was not significant (Guthrie & Picciano, 1995:53).

Table 9:

Indices of the diet quality for cooked, deboned South African A2 lamb cuts

NUTRIENTS	**100 g EDIBLE PORTION** *Nutrient density*[1]			**NUTRIENT QUALITY PER (4200 kJ)** *Index of Nutritional Quality (INQ)*[2]		
	Loin	**Leg**	**Shoulder**	**Loin**	**Leg**	**Shoulder**
Protein	7.11	6.54	5.88	5.95	5.47	5.22
Iron	1.00	2.02	0.09*	0.86	1.74	1.26
Zinc	2.36	1.92	1.33	2.04	1.66	1.14
Vitamin B_{12}	6.11	7.37	5.56	5.06	6.09	4.60

Nutrient Density = ≥ 1.00: good source.
INQ = two or more nutrients ≥2, or four nutrients >1 are regarded as ”nutritious” (Guthrie & Picciano, 1995:53).
* low value due to some missing iron values for cooked shoulder in study.
[1] Calculated using data from table 5 and RDA table in Schönfeldt & Welgemoed. (1996:7).
[2] Calculated using data in table 5 and table 2 in Lee & Nieman (2003:27)

CONCLUSIONS

The majority of the population in most developed countries consume meat (and meat products) that significantly contribute to the nutrient intake. Meat provides a range of amino acids essential for the growth and development of the human body, fats which contribute to energy intake and essential fatty acids, minerals such as iron and zinc in a highly bioavailable form and vitamins, particularly vitamin B_{12} (Enser, 2000:124).

It is evident from this study that lamb also provides a variety of valuable nutrients. Another positive attribute of South African lamb is that it has a high mineral content. Meat from the A age class, fat class 2 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 (chemical) analysis values and the minerals of the cooked cuts. Cooking affected mainly the protein magnesium, potassium and energy values, which were higher in the cooked meat cuts, but also differed significantly between the cooked cuts. There was no significant difference in the iron and zinc values between the cooked cuts. Results showed differences in both trace elements and B vitamins among different cuts, although the differences were not statistically significant.

Furthermore, A age class, fat class 2 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, it can be recommended that lean meat can be consumed in moderation and 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. When Comparing data with that of other countries (USA, Britain, Australia and New Zealand), it shows that the use of non-local data sources can produce differences in the assessment of the nutrient composition and may cause conflicting interpretation of the dietary intake data. The greatest differences observed when comparing data from the USA, Britain, Australia and New Zealand, were for protein, total fat, ash, energy, some minerals as well as some of the fatty acids. Therefore it is clear that the nutrient content of meat is influenced by amount of total fat it contains. As fat content (and therefore also fatty acids) increases, protein content (and amino acids) decreases per 100 g portion, with the concomitant associated increased energy content. The variation in the total fat content could furthermore be attributed to the proportion of fat to lean as suggested by different slaughter masses; natural variation in the fat content between animals, cutting up and trimming techniques, and visible subcutaneous and intermuscular fat included in cuts such as loin chops (Enser, Hallett, Hewett, Fursey, Wood & Harrington, 1998:339).

Therefore, accurate local data on nutrient composition is essential for assessing dietary intakes, determining the relationship between dietary intake and disease occurrence, and for communicating meaningful nutrient information to the consumers. In comparing the newly-determined nutrient values with those currently used in the tables of the MRC (updated meat tables) borrowed from other countries' food composition tables; the most significant observation is probably the lower fat content of lamb as determined. Therefore this study contributes valuable data to more accurately assess dietary intake by providing an accurate nutrient profile of South African lamb. However, this data is on A age class, fat class 2 lambs only (± 7 % SCF), and more research and data is required on the rest of the classification system of South African lamb and mutton to ensure a complete data set.

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REFERENCES

American Meat Science Association. (1995). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Am. Meat Sci Assn. and Nat. Live Stock and Meat Board, Chicago, Illinois.

Association of Official Analytical Chemists International (AOAC). (2005). *Official methods of analysis of AOAC International.* 18th ed. Maryland, USA.

Atwater, W. O., and Bryant, A. P. (1900). *The availability and fuel value of food materials.* In 12th Annual Report Connecticut Agricultural Expt. Station Storrs, 73–110.

Badiani, A., Nanni, N., Gatta, P.P., Bitossi, F., Tolomelli, B. and Manfredini, M. (1998). Nutrient content and retention in selected roasted cuts from 3-month-old ram lambs. *Food Chemistry,* **61:1/2**, 89-100.

Chan, W., Brown, J., Church, S.M. and Buss, D.H. (1996). *Meat products and dishes, supplement to McCance & Widdowson's The food composition of foods*. London. The Royal Society of chemistry, Chambridge.

Charley, H. (1986). *Food Science*. New York. John Wiley & Sons, Inc.

Christopherson, S.W. and Glass, R.L. (1969). Preparation of milk fat methyl esters by alcoholysis in an essentially non-alcoholic solution. *Journal of Dairy Science,* **52,** 1289-1290.

Cobiac, L., Droulez, V., Leppard, P. and Lewis, J. (2003). Use of external fat width to describe beef and lamb cuts in food composition tables. *Journal of Food Composition and Analysis,* 16:133-145.

Codjia, G. (2000). ECSAFOODS, A regional perspective on food composition data activities. AFROFOODS REPORT, meeting of co-ordinators of sub regional food data centres. Dakar, Senegal. 15-17 June:32-45.

Department of Health. Draft Regulations relating to the South African Labelling and Advertising of Foodstuffs as part of the Foodstuffs, Cosmetics and Disinfectants Act, 1972. (http://www.doh.gov.za/department/dir_foodcontr.html) [s.a.].

Enser, M. (2000). *Producing meat for healthy eating*. Proceedings of the 46th International Congress of Meat Science and Technology. 27 August – 1 September 2000, Argentina. p 124.

Enser, M., Hallett, K.G., Hewett, B., Fursey, G.A.J., Wood, J.D. and Harrington, G. (1998). Fatty acid content and composition of UK beef and lamb muscle in relation to production systems and implications for human nutrition. *Meat Science,* 49(3):329-341.

Fellman, J.K., Artz, W.E., Tassinari, P.D., Cole, C.L. and Augustin, J. (1992). Simultaneous Determination of Thiamin and Riboflavin in Selected Foods by High-Performance Liquid Chromatography. Journal of Food Science, 47, 2048 – 2050.

Gebhardt, S.E. and Thomas, R.G. (2002). *Nutrient Value of Foods. U.S. Department of Agriculture,* Agricultural Research Service, Nutrient Data Laboratory, Beltsville, Maryland. Home and Garden Bulletin, 72:58.

GenStat for Windows. (2003). Release 4.2. Fifth Edition. VSN International Ltd., Oxford, UK. SNEDECOR, GW & COCHRAN, WG. 1980. Statistical methods (7th Ed.). Iowa State University Press.

Gericke, G. (2003). Better eating for better health: principles and practices of planning a healthful diet. Unit 4, In *Graduate Readings Volume 3. Fundamentals of Nutrition Security in Rural Development*. (pp. 227-244).

Greenfield, H. and Southgate, D.A.T. (2003). *Food composition data*. Rome. Food and Agriculture Organization of the United Nations.

Guthrie, H.A. and Picciano, M.F. (1995). *Human nutrition*. Mosby. St. Louis, Missouri.

Hoke, I.M., Buege, D.R., Ellefson, W. and Maly, E. (1999) Nutrient and related food composition of exported Australian lamb cuts. *Journal of Food Composition and Analysis,* **12,** 97-109.

Kirton, A.H., Barton, R.A. and Rae, A.L. (1962). The efficiency of determining the chemical composition of lamb carcasses. *Journal of Agricultural Science*, **58,** 381-386.

Kruger, R., van der Spuy, E.H. and Viljoen, A.T. (2003). Nutrition in the rural context Unit 5, In *Graduate Readings Volume 3. Fundamentals of Nutrition Security in Rural Development.* p 344.

Langenhoven, M., Kruger, M., Gouws, E. and Faber, M. (1993). *MRC Food composition tables*, 3rd ed. Medical Research Council. Tygerberg. South Africa.

Latham, M.C. (1997). *Human nutrition in the developing world*. Rome. FAO.

Lawrie, R.A. (1998). *Meat Science*. Sixth edition. Woodhead Publishing Limited. Cambridge England.

Lee, R.D. and Nieman, D.C. (2003). *Nutritional Assessment*. Third edition. McGraw-Hill. New York.

Lewis, J. Milligan, G. and Hurt, A. (1995). NUTTAB95 - *Nutrient data table for use in Australia. Food Standards Australia New Zealand.* Commonwealth of Australia. Vol. 1.

Lombardi-Boccia, G., Martinez-Dominguez, B. and Aguzzi, A. (2002). Total heme and non-heme iron in raw and cooked meats. *Journal of Food Science,* **67:5,** 1738-1741.

Lombardi-Boccia, G., Lanzi, S. and Aguzzi, A. (2005). Aspects of meat quality: trace elements and B vitamins in raw and cooked meats. *Journal of Food Composition and Analysis,* **18,** 39-46.

McCance, R.A. and Widdowson, E.M. (1940). *The chemical composition of foods*. Medical Research Council Spec. Rep. Ser. No. 235. London: His Majesty's Stationery Office.

National Department of Agriculture. (1990). *Agricultural Product Standards Act, 1990. Regulations regarding the classification and marketing of meat.* ACT No. 119 of 1990:9-14.

Ono, K., Berry, B.W., Johnson, H.K., Russek, E., Parker, C.F., Cahill, V.R. and Althouse, P.G. (1984) Nutrient Composition of Lamb of two age groups. *Journal of Food Science*, **49,** 1233-1257.

Purchas, R.W., Rutherfurd, S.M., Pearce, P.D., Vather, R. and Wilkinson, B.H.P. (2004). Cooking temperature effects on the forms of iron and levels of several other components in beef semitendinosus muscle. *Meat Science*, **68,** 201-207.

Sayed, N., Frans, Y. and Schönfeldt, H.C. (1999). *Composition of South African Foods: Milk & Milk products, Eggs, Meat & Meat products*. Supplement to the MRC Food Composition Tables 1991. SAFCOD. Medical Research Council. Cape Town.

SAFCoD. (South African Food Composition Data). (S.a.). Brochure. MRC Nutrition Intervention Programme, PO Box 19070, Tygerberg, 7505. South Africa.

Schönfeldt, H.C., Visser, R.E., van Niekerk, J.M. and van Heerden, S.M. (1996). *The nutritional content of South African beef.* ISBN 0-620-20379X. South African Meat Board. Pretoria.

Schönfeldt, H.C. and Welgemoed, C. (1996). *Composition of South African beef.* ISBN 1-919717-01-X. South African Meat Board. Pretoria.

Schönfeldt, H.C., van Heerden S.M., van Niekerk, J.M., Visser, R.E. and Heinze P. H. (1998). *The nutrient content of South African fresh and frozen chicken.* ISBN0-620-22682X.

Schönfeldt, H.C. (1998). *Effect of age on beef quality*. Ph D Thesis, University of Pretoria.

Smuts, C.M., Kruger, M., van Jaarsveld, P.J. Fincham, J.E. Schall, R., van der Merwe, K.J. and Benadé, A.J.S. (1992). *Prostaglandins, Leukotrienes, Essential Fatty Acids.* **47**, 129-138.

Snedecor, G.W. and Cochran, W.G. (1980). *Statistical methods* (Seventh Edition.). Iowa State University Press. p. 234-35. ISBN 0-8138-1560-6.

Steyn, N., MacIntyre, U., Labadarios, D., Maunder, E., Swart, R., Nesamvuni, A.E., Gericke, G., Huskisson, J., Vorster, H.H. and Dannhauser, A. (2000). *The food and nutrient intakes of children aged 1-9 years in South Africa: The national food consumption survey*. In: Proceedings 6th Biennial Nutrition Congress 2000, From Lab to Land. 16-18 August 2000. South Africa.

United Stated Department of Agriculture. (1989). *Composition of Foods: Lamb, Veal and Game Products*. Agricultural Handbook number 8-17.

Van der Westhuizen, R. (2003). Personal communication.

Whitney, E.N. and Rolfes, S.R. (2002). *Understanding nutrition*. 9 th ed. London. Wadsworth.

Williamson, C.S., Foster, R.K., StanNer, S.A. and Buttriss, J.L. (2005). Red meat in the diet. *Review. British Nutrition Foundation Nutrition Bulletin,* 30, 323-355.