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Nutrient content and carcass composition of South African mutton with a focus on bioavailability of selected nutrients

by

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I declare that the thesis herewith submitted for the MSc degree at the University of Pretoria had not been previously submitted by me for a degree at any other University.

.....	.....
J. Sainsbury	**Date**

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ABSTRACT

Nutrient content and carcass composition of South African mutton with a focus on bioavailability of selected nutrients

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For the Master Scientia in Nutrition

South Africans frequently consume red meat as part of their diet. However the nutrient content of South African sheep meat is derived from other countries. The Red Meat Industry considered it essential to have more reliable data and thus the nutrient content of A2 South African lamb was recently determined and published. This is the next phase of the study in which the right sides of C2 mutton carcasses were used to determine the nutrient and physical (carcass) composition of each raw cut as well as the whole carcass by calculation.

Eighteen mutton carcasses of the most commonly consumed breeds, namely Dorper and Merino, in South Africa were selected. The carcasses were obtained from large abattoirs form three mutton producing regions in South Africa namely Ermelo, the Karoo and Kalahari. Chilled carcass sides were subdivided into ten primal cuts. Three cuts (shoulder, loin and leg) from the left side

were cooked in order to determine the nutrient composition thereof. The cuts were dissected into meat which consists of muscle and intramuscular fat, intermuscular - plus subcutaneous fat and bone in order to determine the physical composition per cut and for the whole carcass. Meat compromise of 63.2% of the carcass, with bone contributing to 20.5% and fat to 16.9%. Results showed differences in the physical composition of South African C2 mutton as it contains on average 47% less fat and 19% more lean muscle, when compared to previous published composition data.

Three cuts (shoulder, loin and leg) from the left side were cooked in order to determine the nutrient composition thereof. Cooking resulted in an increase in the protein and cholesterol concentrations of the cooked cuts. Iron content was higher in the cooked loin and leg but decreased in the cooked shoulder. According to nutrient density, a 100g edible portion of the leg, loin and shoulder have a nutrient density higher than one for protein, iron, zinc and vitamin B_{12} indicating that these cuts are a good source of these specific nutrients. A 100g edible portion of the loin cut contained higher fat quantities than the cooked shoulder and leg cuts. The loin cut also had a higher cholesterol content at 70.8mg compared the 58.5mg cholesterol content in the shoulder and 57.9mg in the leg cut. However, these values were calculated with all associated subcutaneous fat and it is known that many consumers trim on plate, especially the loin cut.

Considering the fact that significant differences were apparent between the current study and previous data derived from other countries, it emphasizes the importance of determining the nutrient composition of South African food products in order to increase the validity of the SA food composition tables.

Food-based approaches targeting the relief of micronutrient deficiency usually encourage the consumption of animal foods together with the consumption of green leafy vegetables (GLV). The inclusion of GLV and red meat, two micronutrient rich foods, can be a strategy based on mutual supplementation to combat nutritional deficiencies as it has the potential to alleviate numerous micronutrient deficiencies including iron and vitamin A deficiency.

ABBREVIATIONS

AMSA	American Meat Science Association
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
ARC	Agricultural Research Council
ARC-ANPI	Agricultural Research Council-Animal Nutrition and Animal Products Institute
ARC:LBD	Agricultural Research Council-Livestock Business Division
CLA	Conjugated Linoleic Acid
DMT	Divalent Metal Transporter
FAO	Food and Agriculture organization of the United Nations
g	gram
GC	Gas Chromatography
GLV	Green Leafy Vegetable
GRAS	Generally Recognised As Safe
HPLC	High Performance Liquid Chromatography
IC	Ion Chromatography
IMF	Intermuscular fat
INQ	Index of Nutritional Quality
kJ	kiloJoules
kg	kilogram
LMY	Lean meat yield
LSD	Least significant difference
MRC	Medical Research Council
mg	milligram
MUFA	Monounsaturated fatty acid
NFCS	National Food Consumption Survey
NRIND	National Research Institute for Nutritional diseases
PCA	Principal Component Analysis
RDA	Recommended Dietary Allowances
RMRDT	Red Meat Research and Development Trust of South Africa
pH	The acidity and basicity of solutions is frequently expressed in terms of a function of the Hydrogen $^{+}$ion concentration. Also defined as $pH = -\log_{10}[H^{+}]$
RPO	Red Meat Producers Organisation
PUFA	Polyunsaturated fatty acid
SA	South Africa

SAFCOD	South Africa Food Composition Data
SAMIC	South African Meat Industry Company
SANAS	South African National Accreditation Services
SCF	Subcutaneous fat
SFA	Saturated fatty acid
%	Percentage
UK	United Kingdom
USA	Unites States of America
USDA	United States Department of Agriculture
µg	Microgram
WHO	World Health Organization

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1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

In 1987, Johnson noted that there is a need for more nutrient knowledge on the composition of foods as consumers are becoming more health conscious and are increasingly focusing on their eating habits and the composition of the food they consume. Considering the current malnutrition situation in South Africa (SA), a developing country, it is evident that nutrition education should be a priority. Nutrition education on selected appropriate foods, to meet the nutritional needs of the individual is based on the nutrient content thereof. However, South African Food Composition Tables do not contain the nutrient composition for most foods consumed in South Africa yet and probably never will. In fact only 41% of the current data contained in the South African Food Composition Tables is based on analysed South African foodstuffs (Sayed, Frans & Schönfeldt, 1999). Latham (1997) defines food composition table as a list of foods with values for the content of selected nutrients in each food type. Food composition tables are often used for nutritional assessment of a population as it provides a means to estimate the nutrient content of food consumed (Greenfield & Southgate, 2003; Latham, 1997). Nutritional values for food are derived from food composition tables by health professionals and workers and can be used as a guide for meal planning.

LITERATURE REVIEW

The United Kingdom updated their nutrient profile for meat in 1995 (Chan, Brown, Church & Buss, 1996) and the United States of America updated their nutrient profile for meat in 1997 in order to improve the quality and availability of the food composition data at national level. The first food composition tables for South African foods were compiled by the Research Institute for Nutritional Diseases (NRIND) of the Medical Research Council (MRC) in 1984 (Langenhoven, Kruger, Gouws & Faber, 1991). Current South African food composition tables are still compiled by the

Medical Research Council (MRC) on an ongoing basis. This is necessary as previous nutrition data on mutton for South African food composition tables was borrowed from the English food composition tables (Langenhoven *et al.*, 1993) but the latest update on mutton (lamb and sheep) which appeared in the MRC's food composition tables of 1999 are derived from the United States Department of Agriculture (USDA) database (Sayed *et al.*, 1999). Meat is a universally valued food and an important source of high-value animal proteins (Valsta, Tapanainen & Männistö, 2005) that contributes significant amounts of bioavailable iron and zinc as well as vitamin A, vitamin E and the B-vitamins to the diet. According to Schönfeldt (1998) meat should be evaluated in terms of its total composition and not only for single nutrients which it is considered to be an excellent source of.

Foods are biological material and vary in composition due to season, geography, cultivar and husbandry (Greenfield & Southgate, 2003). For instance carcasses are dissected into different primal cuts in each country, thereby influencing the exact composition of similar meat cuts in each country (Schönfeldt, 1998). For example, amino acids varies between different parts of the carcasses, and different cutting methods may influence the amino acids detected (Lawrie, 1998). Furthermore, animals in South Africa are slaughtered at different chronological ages, slaughter weights and fatness percentages than in other countries. This also limits the utilization of data, as these factors have a direct influence on the nutrient content of the carcass. The physical composition of an animal, changes as it matures and ages (Micol, Robelin & Geay, 1991) and processing practices differ among countries, such as trimming of subcutaneous fat prior to selling and cooking which also causes changes in nutrient composition (Jamora & Rhee, 1998). Endpoint temperature of cooking leads to moisture loss and thus an increase in concentration of some nutrients and a decrease in the heat-labile nutrients, and again has an effect on the nutrient content (Jamora & Rhee, 1998).

The differences in climate as well as soil content between the countries may influence the nutrient content of the animals' feed and thus the nutrient content of the animals' meat (Greenfield & Southgate, 2003). According to Givens (2005) the fatty acid composition of animal products is not fixed and can be altered in response to changes in the diet of the productive animals. Dietary factors are not responsible for any changes in the body fat distribution of sheep, but it is possible that dietary changes may influence the fat composition of ruminants. These changes in fat composition may significantly affect the fatty acid profile of ruminants (Casey & Webb, 1995). Most of South African sheep and lambs are raised in open fields and on pastures where they feed on the grass and shrubs. Givens (2005) states that meat from animals that feed on fresh grass

has added benefits as fresh grass contains high amounts of Conjugated Linoleic Acid (CLA) and it is proposed that the meat will also contain high amounts of CLA (McGuire & McGuire, 1999).

South African consumers frequently eat meat as part of their daily diet (ACNielsen, 2001). The consumer's behaviour is increasingly driven by product quality and health consciousness, with a newly emerging consumption pattern focused on "healthy eating" (Verbeke, 1999). Production of uniform, safe, nutritious and lean mutton products will be highly acceptable by consumers (Shackelford, Leymaster, Wheeler & Koohmaraie, 2003). However, the sheep industry competes with other animal proteins such as beef, pork, poultry and fish for an affordable product for the consumer, who has many other choices of high quality meat. Table 1 illustrates a comparison between the nutritional composition of mutton, beef and pork and shows that mutton and beef contain less fat than pork and high quantities of iron and zinc. In this competitive environment, the sheep industry must monitor and react to the changing preferences of the consumer.

TABLE 1: A comparison of the nutrient content of 100g untrimmed mutton, beef and pork from South African Food Composition Table (Sayed *et al*., 1999)

Nutrients	Unit	Mutton*	Beef	Pork
		Raw	Raw, age C	Raw
Moisture	g	60.7	60.7	49.8
Energy	kJ	1087	1057	1535
Protein	g	16.9	18.4	13.9
Fat	g	21.6	20.1	35.1
Cholesterol	mg	72	62	74
Saturated fatty acids	g	9.5	9.2	12.4
Mono-unsaturated fatty	g	8.9	8.9	15.9
Poly-unsaturated fatty	g	1.7	0.28	3.8
Iron	mg	1.6	1.9	0.7
Zinc	mg	3.3	3.5	1.6

* Meaning older animals and according to the South African Red Meat Classification system it implies animals of the AB, B and C age (SAMIC, s.a)

Physical carcass composition

Carcass composition is influenced by various factors including gender, age, breed, slaughter weight and fatness level (Kempster, Croston & Jones, 1987; Berg & Butterfield, 1978). The sheep carcasses mainly consist of proportions of muscle, fat and bone of which muscle is the most important part contributing to the diet of consumers (Cloete, Hoffman, Cloete & Fourie, 2004). Bones form the largest part of the inedible portions. The composition of the edible portion (muscle and fat) varies, and is influenced by slaughter weight, sex, shape, feed and breed (Berg & Butterfield, 1978). Age and fatness levels of the animal will also affect the physical composition

of the different cuts (Kempster *et al.,* 1987). Consumers prefer meat cuts with high lean meat yield (LMY %) to carcass with higher proportions of fat (Johnson, Purchas, McEwan & Blair, 2005). Knowledge of the carcass composition is necessary to provide the preferred cut to the consumer as such or by further trimming of the cut to the consumers' preference (Hopkins, Watton, Gamble, Atkinson, Slack-Smith & Hall, 1995).

With the correct analysis and interpretation of the carcass composition of South African mutton, the nutrient content and quality characteristics of South African mutton can effectively be described. When the accurate data on the nutrient content of South African mutton is incorporated into the food composition tables of the MRC, the data will serve as a reliable standard of reference for the health professionals and the food industry.

Nutrient analysis

Consumers are increasingly more focused on the quality and nutritional characteristics of foods including meat and meat products. Therefore, as consumers are becoming more health conscious, they are increasingly focusing on their eating habits and nutrient intake as well as food safety (Garnier, Klont & Plastow, 2002). The amount of fat in the diet and its saturated fatty acid content are considered major risk factors for coronary heart disease (Sañudo, Enser, Campo, Nute, Maria, Sierra & Wood, 2000). Consumers' behaviour is increasingly driven by product quality and health consciousness with a newly emerging consumption pattern focused on "healthy eating" (Verbeke, 1999). The amount of fat and cholesterol food products contain, as well as the long term effect thereof are of an increasing concern. High quantities of visible fat are often removed either before cooking or during the meal as it discourages the consumer, especially the younger consumer (Sañudo *et. al*., 2000).

Although high intakes of some animal products are associated with increased fat consumption and may lead to gaining weight (Givens, 2005), Enser (2000) emphasise the numerous nutritional benefits associated with meat. Fat associated with the consumption of red meat, in general, may increase the risk for colon cancer as it promotes the excretion of bile which can be converted to carcinogens (Biesalksi, 2005). However, the fat associated with the consumption of mutton contains essential fatty acids and Conjugated Linoleic Acid (CLA) (McGuire & McGuire, 1999) that have numerous beneficial effects for the body (Enser, 2000). Ruminant fat naturally contains the fatty acid CLA with pharmacological activity. CLA occurs naturally in ruminants as it is formed by a bacterial isomerase in the rumen as the first stage in the bio hydrogenation of linoleic acid to stearic acid (Enser, 2000). The CLA isomer commonly found in pasture fed animals such as SA lamb and mutton, *cis*-9 and *trans*-11, was recently given the trivial name rumenic acid as this fatty

acid is produced in the rumen of animals (McGuire & McGuire, 1999). Recent studies confirmed that CLA found in meat from ruminants holds numerous benefits as it has anti-oxidant and anti-cancer properties (McGuire & McGuire, 1999).

Nutritional values for foods are derived from food composition tables; therefore, as in many other countries, South Africa is actively involved in analysing food for the compilation of food composition data tables. Many countries use one national food composition table that contains foods commonly eaten in the country. Some of the data analysed in one country is often incorporated into the food composition tables of other countries. Problems could arise where the different countries use different methods to analyse nutritional composition as well as different measuring units and cooking methods. Jamora and Rhee (1998) explain that cooking leads to moisture loss and thus an increase in concentration of some nutrients and decrease in heat-labile nutrients. Different techniques, standards and method of analysis are used to cut animal carcasses into primal cuts in the different countries, which may also affect the nutritional values (Schönfeldt, 1998). The difference in climate, soil content and water composition of the various regions and countries affects the nutrient content of the animal feed, as well as the production of vitamin D in the meat itself (Greenfield & Southgate, 2003). Post-mortem factors, which differ among countries, such as fat trim levels and cooking can also cause changes in nutrient composition (Jamora & Rhee, 1998). Due to these differences between countries it is obvious that food composition tables are not internationally applicable and it is therefore important that each country has their own food composition tables (Deharveng, Charrondiere, Slimani, Southgate & Riboli, 1999).

Nutrient sources and interactions comparing meat and leafy green vegetables

Deficiency of trace minerals in humans may be a result of inadequate consumption of minerals in the diet or a decrease or impaired absorption in the presence of adequate dietary intake (Sandström, 2001). Maize and bread remain the most commonly consumed foods in South Africa with the consumption of vegetables remaining low (Van Vuuren, 2006), and could be the reason for an estimated 33% of children in South Africa, suffering from vitamin A deficiency and 21% from iron deficiency anaemia (Dhansay, Marais & Labadarios, 2008). Interventions to combat these micronutrient deficiencies such as fortification and supplementation are costly and may produce other problems such as toxicity and changes in colour and flavour of foods.

Plants form part of most diets around the world and are a source of energy in most developing countries (Southgate, 1998). Green leafy vegetables (GLV) have long been recognised as the most affordable nutrient dense food containing protein, iron, calcium, vitamin C, vitamin A and

folic acid (Aletor, Oshodi & Ipinmoroti, 2001). Therefore, inclusion of GLV with red meat, two micronutrient rich foods, in combination in the diet, can be a better strategy to combat nutritional deficiencies (Agte, Tarwadi, Mengale & Chiplonkar, 2000).

When consuming foods with different micronutrient contents, there are a number of inter-relations and interaction between the micronutrients that might occur (Sandström, 2001). Most micronutrients appear to utilise specific absorptive mechanisms and are therefore not vulnerable to these interactions. However, minerals such as iron and zinc with chemical similarities can compete for transport proteins or other uptake mechanisms, as well as for chelating organic substances, which can hinder absorption. The quantitative consequences of these interactions will depend on the relative concentrations of the nutrients (Sandström, 2001). In a similar way trace element deficiencies could affect general absorptive capacity, as well as specific mechanisms needed for uptake of other micronutrients. A poor nutritional status with regard to vitamins affects mucosal integrity and can thereby affect absorption of other nutrients. Considering the high number of South Africans with micronutrient deficiencies it indicates that a great need exists for nutrition knowledge regarding micronutrient interaction.

The potential of including GLV and red meat as a viable food based strategy is proposed. Red meat contains significant amounts of bioavailable heme minerals but is mostly consumed in insignificant amounts in the communities due to cost. On the other hand GLV is gathered as the most utilized food coping strategy by those informal settlements in rural areas (Kruger, Schönfeldt & Owen, 2008), but contains mostly unavailable minerals due to the food matrix (Aletor *et al*., 2001; Kumari, Gupta, Lakshmi & Prakash, 2004). By combining these foods in a cost effective manner it is proposed that the nutrients, particularly the minerals, will be more absorbable based on complementary interactions (Agte *et al*., 2000).

MOTIVATION FOR THE STUDY

Providing adequate nutrition and safe food remains one of the most important challenges facing mankind in the future (Vorster & Hautvast, 2002). Nutritional deficiencies are seen globally and most developing countries are faced with the double burden of nutritional deficiencies and excesses (Shetty, 2002). Not only do all people eat nutrients in the form of food, but their health depends on the combination and quantity of nutrients in the food consumed, within a given time period.

Although the nutrient content of A2 lambs has been determined (Van Heerden, Schönfeldt, Kruger & Smith, 2007) there remains a lack of information on the nutrient content of SA mutton (C2). With the availability of the nutrient content and CLA values for SA mutton of age class C and fatness level 2, it will be possible to compare the nutrient composition of lamb (A2) with mutton (C2) and study chronological changes.

Previous values published by the Medical Research Council (MRC) in 1999 do not represent South African mutton (C2). Due to the lack of nutrient content information of South African mutton (C2), research in this regard is essential for the Red Meat Industry.

STRUCTURE OF THE STUDY

The dissertation will be presented in the format of articles and will be presented in the following chapters:

CHAPTER 1: Structure of dissertation
CHAPTER 2: Introduction and problem statement
CHAPTER 3: The physical composition of raw and cooked South African mutton
CHAPTER 4: The nutrient content of South African mutton
CHAPTER 5: Micronutrient interactions between mutton and green leafy vegetables
CHAPTER 6: Conclusion and recommendations

Relevant references for each chapter are provided at the end of each chapter.

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2

RESEARCH DESIGN AND METHODOLOGY

THE RESEARCH OBJECTIVES

The specific objectives were:

1. To determine the nutritional composition of selected cuts from Age C*, fat class 2**, mutton (C2) from South Africa.

2. To compare the nutrional composition data of Age C, fat class 2, (C2) mutton produced in South Africa with nutrional composition data of A2 lamb from South Africa.

Mutton in this study is only obtained from: *the oldest animals (7-8 inciscors) and **fat class with at least 1 but not more than 4mm subcutaneous fat.

The overall research objective will be addressed through physical dissection and chemical analysis of fat and meat (raw and cooked) from Age C, fat class 2, mutton from South Africa.

Null hypothesis (H_0)

1. There will be no difference between the nutritional composition of South African C2 mutton and the MRC 1999 food composition tables.

2. There will be no significant difference in the nutritional composition of the South African C2 mutton when compared to A2 lamb from South Africa.

PURPOSE OF THE STUDY

Currently there is no existing scientific literature on the nutrient content of South African mutton. Although South African sheep originated from international breeds, other factors that may

influence the nutrient content includes the different dissection of primal cuts between the different countries as well as different slaughtering weights, age and fatness levels and feeding regimes (Schönfeldt, 1998). The difference in soil, climate and water composition of South Africa may influence the nutrient content of the animals' feed and thereby also affect the micronutrient content of mutton. Previous food composition values reported by the Medical Research Council (MRC) in 1999 are not representative of South African mutton (C2) as it was obtained from the USDA. Meat plays an important role in the South African diet, and the results from this proposed study could play an important role in the understanding of the nutritional properties of SA mutton (C2).

The nutrient profile of A2 lambs has been determined (Van Heerden, Schönfeldt, Kruger & Smith, 2007) with results indicating that South African lamb (C2) contains 41% less fat than previously reported by the MRC. With the availability of the nutrient values for A2 and C2 it will be possible to effectively determine the chronological effect on the nutritional composition of lamb and mutton. The nutrient profile for SA mutton (C2) has not yet been determined and therefore necessitated this study.

EXPERIMENTAL DESIGN

A framework used according to which the data was collected in order to investigate the research question. Refer to Figure 1 for a research design for this study.

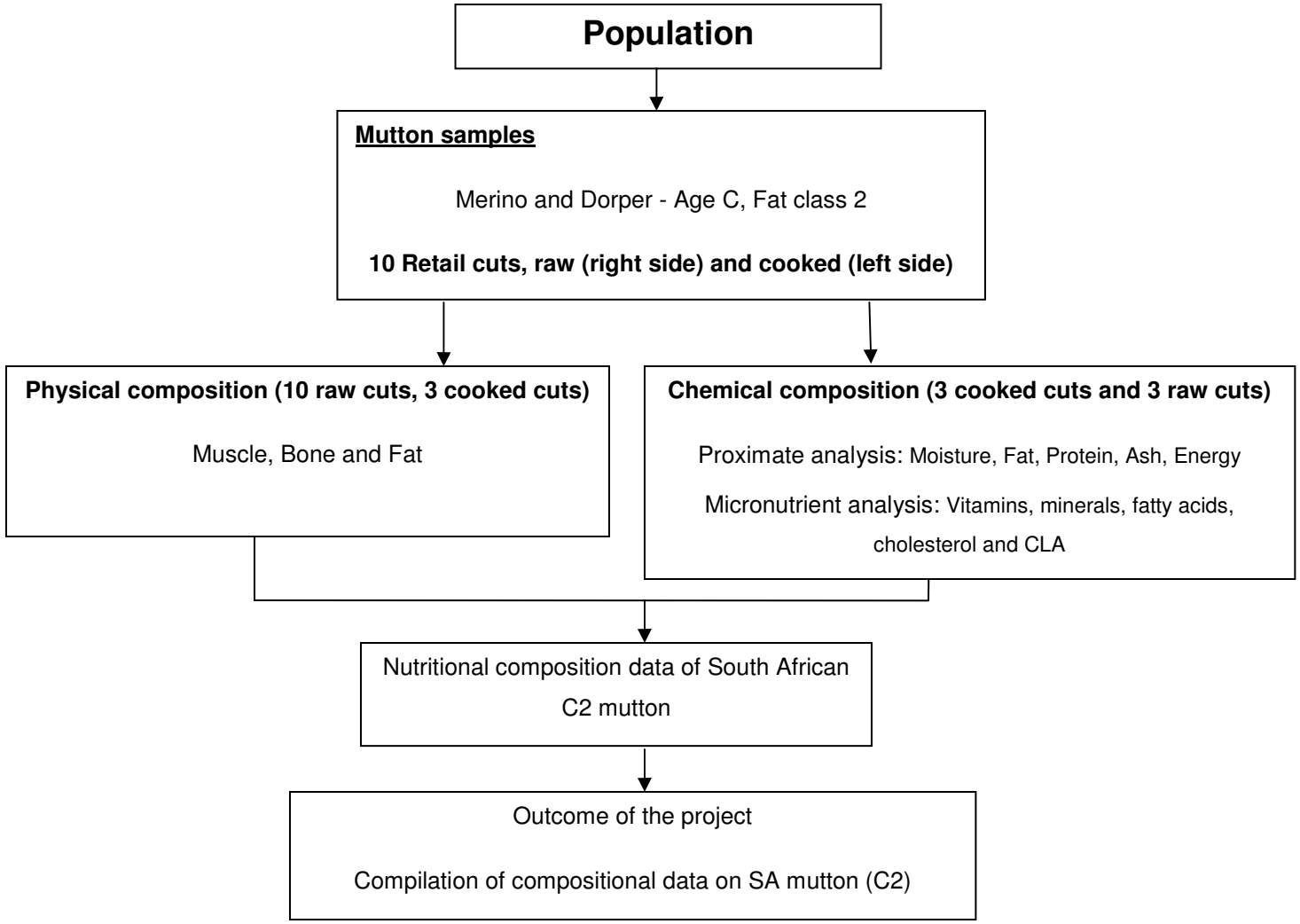

FIGURE 1: Broad research framework

CONCEPTUALISATION

Certain concepts are fundamental to this study and were identified from an extensive literature review conducted for the various components of this study (see also Chapters 3, 4 and 5). These concepts can be defined as follows:

Sample (sample population)

For this study, sample refers firstly to the animals that were selected namely age class C, fatness level 2. Secondly it refers to the individual retail (wholesale) cuts that were selected and thirdly, to the three portions of meat cuts that were subdivided in 3 parts namely lean (meat), fat and bone.

South African Red Meat Classification System for lamb and sheep

The Red Meat Classification System uses the main characteristics of beef, mutton (for this study), lamb and goat to classify the carcasses in order to make the purchase of red meat as simple as possible for consumers. When referring to the class of a carcass, both the age class and fatness class are implicated (SAMIC, s.a.). The main characteristics used to classify mutton for this study are the age of the animal and the fatness of the carcass. The age classes are known as:

A = meaning the youngest animals (0 incisors)
AB = meaning older animals (1-2 incisors)
B = meaning even older animals; (3-6 incisors) and
C = meaning the oldest animals (7-8 incisors)

The fatness classes are known as class zero (no fat) to class 6 (excessively over fat). According to the fatness classification of sheep, (National Department of Agriculture, 1990, in SAMIC, s.a), the seven fat classes are described as follows:

TABLE 1: Guidelines for fat classification of sheep (SAMIC, s.a)

Fatness class	Guideline for the determination of the thickness of the subcutaneous fat layer (mm)	Guideline for the percentage subcutaneous fat
0	Zero	Less than 1.0
1	Less than one	Not more than 5.6
2	At least 1 but not more than 4	> 5.6, but not more than 8.6
3	More than 4 but not more than 7	> 8.6, but not more than 11.6
4	More than 7 but not more than 9	> 11.6, but not more than 14.6
5	More than 9 but not more than 11	> 14.6, but not more than 17.6
6	More than 11	> 17.6

In this study, animals were selected from the C age class with fat class of 2.

Primal (wholesale) cuts for lamb and mutton

In the South African meat industry, a sheep carcass is usually subdivided into the following ten primal (wholesale) cuts: neck, thick rib, flank, shoulder, breast, rib, loin, chump, leg and shins (SAMIC, s.a).

Subcutaneous fat (SCF)

Subcutaneous fat comprises the peripheral layer of fat to the level of the connective tissue covering the peripheral muscle layer, but excluding *M. cutaneous trunci* which lies on top of the subcutaneous fat (Kempster, 1980).

Intermuscular fat (IMF)

Intermuscular fat (IMF) comprises of the fat lying between the muscles, together with thin connective tissue, small blood vessels and small quantities of muscle that are physically difficult to separate (Kempster, 1980).

Meat

In this study, meat comprises of muscle as well as intramuscular fat.

Carcass (physical) composition

The carcass composition performed in this study, comprises the proportions of body tissue present in a carcass and it refers to the composition of the anatomical proportions of the various tissues e.g. meat (muscle + intramuscular fat), fat (intermuscular + subcutaneous fat) and bone. Physical composition refers to either the carcass or the cut composition.

Nutrition

Nutrition is the science of foods, the nutrients and substances therein, their action, interaction, and balance in relation to health and disease, and the process by which the organism ingests, digests, absorbs, transports, utilizes, and excretes food (Wardlaw & Insel, 1996).

Nutrients

Nutrients are chemical substances in food such as vitamins, minerals, fat, protein and water, which nourish the body by providing energy, building materials, and factors that regulate needed chemical reactions (Wardlaw & Insel, 1996).

Nutrient content

Nutrient content refers to the variety and quantity of vitamins (fat- and water-soluble), minerals, fatty acid profile (total fat content), total cholesterol and amino acid profile (total protein content). The nutrient value of a food can be expressed in terms of its content of nutrients and energy and how each relates to the Recommended Dietary Allowances (RDA) for that specific food (Whitney & Rolfes, 2002).

Nutritional value

Nutritional value is an indication of the quantity of a specific nutrient and its absorption or bioavailability of the nutrient from the food item (West & Schönfeldt, 2002).

Edible portion

Edible portion refers to the product as consumed by a consumer. In this study edible portion includes meat (muscle + intramuscular fat) and fat (subcutaneous and intermuscular fat), and not the bone.

Dry heat cooking method

Dry heat methods are designed to maximise the quality of muscle proteins. Tender meat cuts are well suited for dry heat cooking because of their relatively high proportion of muscle protein and

reduced quantity of collagen. No water or fluid is added during or prior to the cooking process (McWilliams, 2005).

Moist heat cooking method

Moist heat cooking methods include the addition of water and are designed to provide sufficient time for collagen to be converted to gelatine without toughening the muscle proteins (McWilliams, 2005).

Food composition tables

Food composition tables consist of an alphabetical list of selected foods with data on the content of selected nutrients in each food. It also gives information on the portion, composite sample, collection and analysis of the composition of foods (Southgate, 1998). The tables are organised according to the classification of foods into food groups (West & Schönfeldt, 2002). From this study, the nutrient content of three raw and cooked mutton cuts will be available to be included in the South African food composition tables.

MATERIALS AND METHODS

Sampling for carcass composition and nutrient analysis

Eighteen mutton carcasses (9 Dorper and 9 Merino) with an average mass range of 10.5 kg per side were randomly selected. Owing to the fact that carcasses had to be representative of the South African mutton market, nine Dorpers and nine Merinos were used as these are the two most commonly used breeds for mutton in South Africa (Van Heerden *et al.,* 2007). All carcasses were selected from the C age and fat class two. The carcasses originated from three different mutton producing regions (Karoo, Kalahari and Ermelo) in South Africa (Table 2). The carcasses were classified according to the South African classification system by a qualified classifier at the abattoirs. Commercial slaughtering and dressing procedures were followed. The kidneys were removed and weighed for each carcass. The mutton carcasses consisted of the skinned, eviscerated body from which the head, feet, kidney and kidney fat had been removed. On the day after slaughter, the chilled carcasses were sectioned down the vertebral column by band saw at the abattoir. Selected carcasses were transported in a refrigerated truck (4 - 6℃) to the Meat Industry Centre of the ARC-LBD, Irene, where physical dissection continued the following day.. Upon arrival, all the carcasses were weighed, covered with plastic wrap to prevent moisture loss and chilled at 4℃ overnight.

TABLE 2: Experimental design for the evaluation of carcass and chemical composition of South African mutton (C2)

Class	Breeds (n=2)	Area (n=3)
C2	Dorper (n=9 per class)	Karoo (n=3)
		Kalahari (n=3)
		Ermelo (n=3)
	Merino (n=9 per class)	Karoo (n=3)
		Kalahari (n=3)
		Ermelo (n=3)
	Total carcasses = 18	

Sample preparation

The carcasses were weighed at Irene ARC:LBD prior to being sub-divided into the respective 10 primal cuts (Figure 2). A trained deboning team at Irene ARC:LBD was responsible for the physical dissection and they subdivided each side of the carcass into the following 10 primal cuts: neck, thick rib, flank, shoulder, breast, rib, loin, chump, leg and shins in an environmentally controlled de-boning area at 6ºC. After recording the weight of each cut from the right side, the cuts were further dissected into meat (muscle + intramuscular fat), fat (subcutaneous + intermuscular) and bone. The meat (muscle + intramuscular fat), fat (subcutaneous + intermuscular) and bone content of each cut from the right sides of the carcasses was weighed and used to calculate the cut and carcass composition. The primal cuts of the left sides of the carcasses were vacuum packed and frozen till required for cooked analysis.

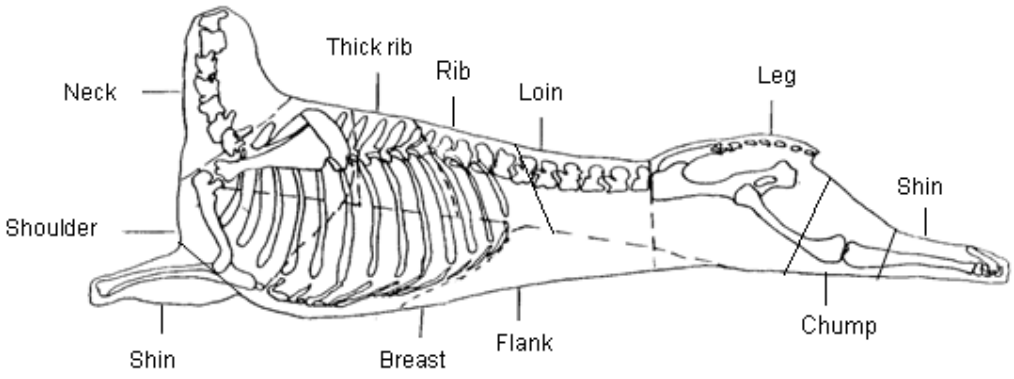

FIGURE 2: Dissection diagramme (Casey, 1982)

Three cuts (leg, loin and shoulder), representing the most commonly consumed cuts, taken from both sides, were used to determine the cooked (left side) and raw (right side) physical and nutrient composition. The three cuts (leg, loin and shoulder) were defrosted for 48 hours at 6ºC prior to cooking according to standardised moist or dry heat cooking methods in identical Mielé ovens at 163°C to an internal temperature of 73°C measured in the geometrical centre of the cut (American Meat Science Association, 1995). Cooking losses were measured for both cooking methods (dry and moist) as part of the standard procedure. After cooling down, the cuts were weighed and then dissected into meat (muscle + intramuscular fat), fat (subcutaneous + intermuscular fat) and bone. These weights were recorded and used to determine the physical composition of each cut (Figure 4).

After weighting the meat (muscle + intramuscular fat), fat and bone for each raw and cooked cut of each carcass, the fat and muscle portions were prepared for proximate and nutrient analysis. Due to financial constraints and in order to comply with the Draft Regulations (2004) relating (http://www.doh.gov.za/department/dir_foodcontr.html), to the Labelling and Advertising of Foodstuffs as part of the Foodstuffs, Cosmetics and Disinfectants Act, 1972, a composite of three carcasses was pooled and used as a basis for studying the nutrient composition. The use of composite samples for analysis rather than individual samples is justified because of funding constraints and has been an accepted approach in food composition studies (Greenfield & Southgate, 2003). Therefore the samples analysed for this purpose are those of the 3 cuts (leg, loin, shoulder) of the C2 class. Care was taken in the design to ensure statistical reliability of the data. A composite sample (3 carcasses of 1 age group, 1 fat code, 2 breeds, and 3 cuts), of raw (left sides) and cooked (right sides) meat and subcutaneous fat was analysed (Table 3). All foods vary in nutrient composition and its contribution of nutrients to the diet, therefore only the nutrients in meat that are known to be a significant source were analysed.

To prepare the composite samples of 18 animals for proximate and nutrient analysis, the meat (muscle + intramuscular fat) and fat (subcutaneous + intermuscular fat), respectively, of all three repetitions for each raw cut, from the **right** sides, (n = 10 cuts) and three cooked cuts from the **left** sides, were combined and cubed, thoroughly mixed and then minced, first through a 5 mm and then through a plate with 3 mm diameter holes. Samples of 300 g meat (muscle + intramuscular fat) and separable fat (subcutaneous + intermuscular fat) were homogenized with an Ultra Turrax T25 homogenizer after mincing and vacuum packed (Figure 3) prior to the meat being freeze-dried and sent to the ARC analytical laboratory at Irene for proximate analysis (macronutrients analysed). The ARC laboratory was used as it forms part of the ARC:LBD protocol.

TABLE 3: Experimental design for nutrient analysis of South African mutton (C2)

18 Age class C, fat class 2 mutton carcasses					
9 Dorper			9 Mutton Merino		
Ermelo		Kalahari		Karoo	
3 Dorper	3 Merino	3 Dorper	3 Merino	3 Dorper	3 Merino
Macronutrients, micronutrients and fatty acid profile of 3 raw cuts (right side) and 3 cooked cuts (left side) for each breed in each area, will be analysed					

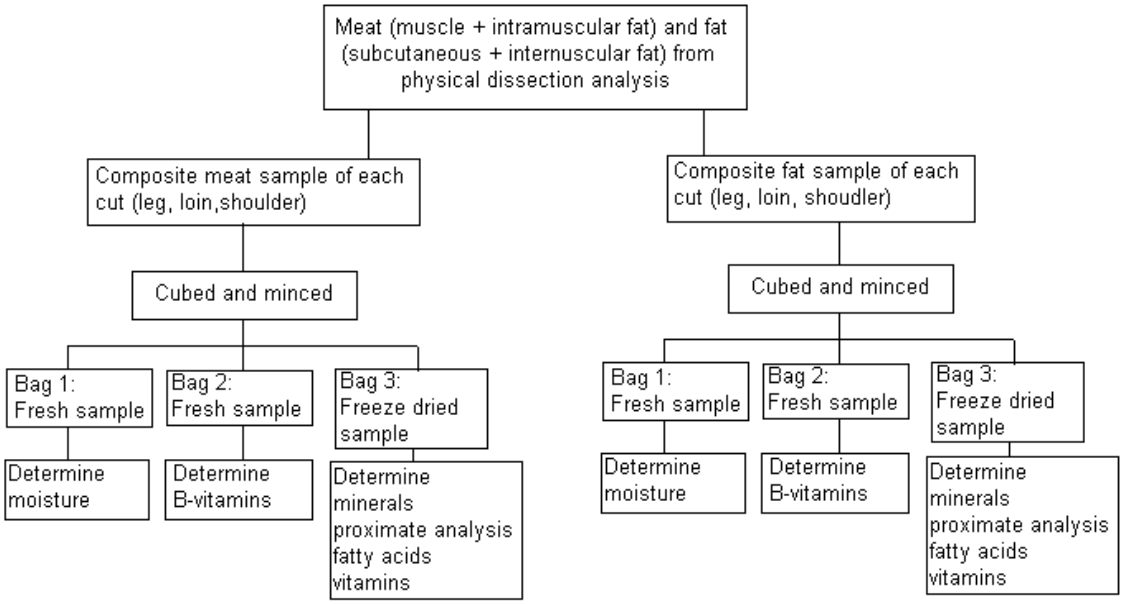

FIGURE 3: Samples used for determining nutrient analysis

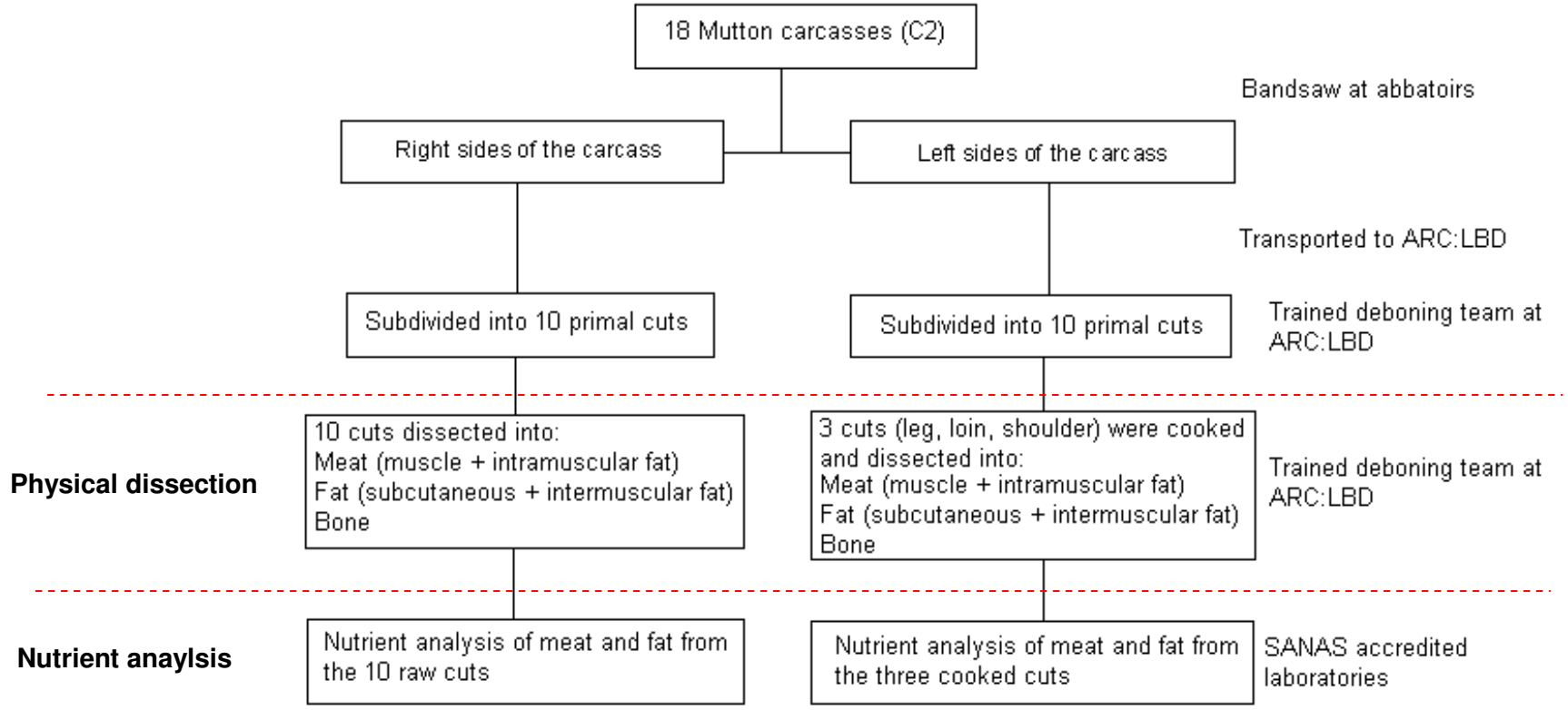

FIGURE 4: Flow diagramme of analysis

The meat (muscle + intramuscular fat) and fat (subcutaneous + intermuscular fat) of each of the three (leg, loin and shoulder) primal cuts of one side (**right**) were analysed for raw nutrient content and three primal cuts of matching side (**left**) were analysed for cooked nutrient content (proximate, vitamins, minerals, fatty acid and cholesterol). The raw and cooked nutrient data of the three cuts was compared based on the assumption, (Kirton, Barton & Rae, 1962) that the chemical composition of the two sides is similar or almost identical.

All the analytical procedures (Table 4) for the nutrient content of the mutton samples were done on a double blind basis in the various laboratories that form part of the South African National Accreditation Services (SANAS). Moisture, cholesterol, ash, fat, fatty acids, vitamin B_1 and B_2 were analysed at the ARC analytical laboratory at Irene. Analysis to determine the mineral content was completed at ARC-Institute for Soil, Climate and Water and vitamin B_3, B_6 and B_{12} were analysed at SABS commercial.

TABLE 4: Methods used for the nutrient analysis of raw and cooked mutton (C2)

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)
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 B_3 B_6 B_{12}	High Performance Liquid Chromatography (HPLC) (Fellman, Artz, Tassinari, Cole & Augustin, 1992) Official Method 961.14 AOAC (2005) Official Method ALASA 7.2.3 (Strohecker & Henning, s.a) Official Method AOAC 986.23 (2005)
Fatty acid profile and CLA	Gas Chromatography (GC) (Christopherson & Glass, 1969)
Cholesterol	Gas Chromatography (GC) (Smuts, Kruger, Van Jaarsveld, Fincham, Schall, Van Der Merwe & Benadé, 1992)

Proximate analysis

Total fat

For determination of total fat, the AOAC method 960.39 (2005) was used where the content of a 2g freeze-dried sample was used to ensure that all the moisture had escaped. The Tecator Soxtec System 1034 extraction unit with reagent petroleum ether (40-60°C) was used for the extraction.

Moisture

For determination of moisture content the weight loss of a 5g sample was measured in triplicate (AOAC, 2005).

Total ash

The total ash is the inorganic matter of a sample and analysed according to the AOAC method 920.153 (2005). The organic matter of a sample is removed by heating at 550 ℃ overnight. The remaining residue is inorganic matter (ash).

Protein

The analysis is based on the Dumas Combustion method, AOAC 992.15 (2005). The sample is combusted at ± 1100 ℃ – 1350 ℃ and 10 cm^3 of the sample gas is analyzed. A thermal conductivity cell detects the difference in thermal conductivity caused by the presence of Nitrogen. A conversion factor of 6,25 was used in the calculation of the protein content. Duplicate samples were analysed.

Food energy content

The energy content was calculated from the percentage protein and fat making use of the following factors:

Energy (kJ / 100g) = 37 (% fat) + 17 (% protein) + 17 (% carbohydrates) (Atwater & Bryant, 1900)

Fatty acid profile (including CLA)

A gas chromatographic method is used for the determination of long chain fatty acids. The fat extracts are trans-methylated with methanol-potassium hydroxide. Fatty acid methyl esters are extracted with n-hexane and analysed by gas liquid chromatography with flame ionisation detection. Nonadecanoic acid (C19:0) is used as internal standard (Christopherson & Glass, 1969).

Total cholesterol

Fat and cholesterol are extracted by soxtec, followed by a saponification-extraction step and clean-up procedure. The cholesterol content is then determined by gas chromatography with flame ionization detection. Stigmasterol is used as an internal standard (Smuts *et al.,* 1992).

Water soluble vitamins

Thiamine (Vit B_1) and riboflavin (Vit B_2) were determined according to HPLC technique with fluorescence detection (Fellman et al., 1992). All analysis were performed in duplicate. Niacin (Vit B_3) was determined according to a colorimetric method AOAC 961.14 (2005) and pyridoxine (Vit B_6) according to an method. Cyanocobalamin (Vit B_{12}) was determined using a turbidmetric method AOAC 986.23 (2005).

Minerals

The following minerals were determined: sodium, potassium, iron, magnesium and zinc. Freeze-dried samples were ashed, dissolved with hydrochloric acid and analysed with an Ion Chromatograph (IC) by a sub-contracted laboratory.

DATA COLLECTION

According to Mouton (1996), "The objective of data collection is to produce reliable data". Therefore the first step was to collect the raw data. For this research study raw data entailed capturing of weights of all the carcasses and cuts onto laboratory reports by hand. The physical cut composition data was captured by hand on a physical dissection data sheet in the abattoir (Appendix A). The same procedure was followed by the analytical laboratory during the determination of the nutrient and chemical content of the samples. All raw data obtained was entered, coded and checked on the spreadsheets using Microsoft Excel (2000), before statistical analysis were done.

STATISTICAL ANALYSIS

Carcass composition

Data was statistically analysed using the GenStat for Windows (2000) statistical computer programme. The significance of variables measured for each sample was tested by means of a one-way factorial analysis of variance (ANOVA) testing for fat class (unbalanced). Breeds and areas were used as the main factor and tested at a significance level of 95% ($p \leq 0.05$). If the sample main effect was significant, Fisher's protected t-test least significant difference (LSD) was applied to determine the direction of the differences between mean values (Snedecor & Cochran, 1980).

Nutrient composition

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

RESULTS

In Chapter 3, the carcass composition is discussed (as composition) in terms of the, meat (muscle + intramuscular fat), fat (subcutaneous + intermuscular fat) and bone that was determined by expressing the yield of each type as a percentage of the carcass side weight. The results of the analysis of variance (ANOVA) are presented in tables and then discussed. The results for the meat, fat and bone are presented in a bar graph for visual interpretation of results.

The nutrient analysis of South African C age class, fat class 2 is presented in Chapter 4. The results are discussed as raw and cooked mutton, as three raw and cooked cuts and their contribution to the Recommended Dietary Allowances (RDA). The results of the analysis of variance (ANOVA) are presented in tables and then discussed.

Reliability

Reliability depends on consistency. Cooking of the mutton cuts was performed in a SANAS accredited laboratory according to standardised methods to ensure accuracy, precision, repeatability as well as reliability. Duplicate and sufficient replications of each sample were used to ensure statistically reliable data. A proper statistical plan and analysis, in this case GenStat for Windows (2000) statistical programme were implemented during the study to ensure reliable results.

Validity

All sampling was representative and handled with accuracy (Babbie & Mouton, 2002). A proper sampling plan was followed with representative samples from each region. Sufficient replication of each sample was used to ensure statistically reliable data. Control samples formed part of the daily routine in the analytical laboratory to ensure the quality.

Outcome of the study

The nutrient results obtained from this study will form part of the MRC's Food Composition Tables of South Africa and aid the health professional in determining the nutritional content of a diet and assessing the nutritional status of population.

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3

THE PHYSICAL COMPOSITION OF RAW AND COOKED SOUTH AFRICAN MUTTON

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ABSTRACT

The objective of this study was to determine the physical composition of cuts of South African mutton carcasses from the C age class and fat class 2. For this study, 18 mutton carcasses of the most commonly consumed breeds in South Africa (9 Dorper and 9 Merino) were selected. The carcasses were obtained from large abattoirs from three mutton producing regions in South Africa (Ermelo, Karoo and Kalahari). Chilled carcass sides were subdivided into ten primal cuts. The cuts were dissected into meat (muscle + intramuscular fat), subcutaneous fat (SCF) and bone in order to determine the physical composition per cut and for the whole carcass. Muscle compromise of 63.2% of the carcass, with bone contributing to 20.5% and fat to 16.9%. No significant differences in the composition of the ten wholesale cuts were found between the three different regions included in this study. Results showed differences in the physical composition of South African mutton when compared to previous published data on mutton composition. South African mutton (C2) contains on average 47% less fat and 19% more lean muscle than previously published data. The soft tissue of the carcass was analysed for % total fat, protein, ash and moisture and results indicated that cooked soft tissue contains 76.5% more fat and 30.5% more protein than raw soft tissue.

Keywords: Carcass composition, mutton, yield, fat content, Dorper, Merino, South Africa

INTRODUCTION

A mutton carcass contains edible as well as inedible components. Bones are the largest proportion of inedible portions, with the composition of the edible portion varying, and being influenced by a number of factors. Carcass composition comprises of this proportion of muscle, fat and bone in the sheep

carcass and is affected by the slaughter weight, sex, shape, nutrition and breed of the animal (Berg & Butterfield, 1978). According to Kempster, Croston and Jones, (1987) the physical composition of certain cuts may vary between different ages and different fatness levels of the animal. The carcass contains a small amount of fat at birth, and the fat increases slowly until the fattening phase sets in and fat is deposited at an increasing rate (Berg & Butterfield, 1978). Slaughter weight influences the carcass composition drastically as the muscle growth of the animal slows fat deposition after puberty. As muscle grows faster than bones, a higher slaughter weight will also lead to a higher muscle to bone ratio which can affect the marketability of the meat (Berg & Butterfield, 1978).

The percentage of bone in the mutton carcass decreases with age resulting in 15% of the mutton (C2) carcass consisting of bone and 53% of lean muscle (Kempster *et al*., 1987). Kempster *et al*. (1987), further explains that subcutaneous fat grows faster than intramuscular fat. Of the total fat in a mutton carcass, 40% is intramuscular and 47% is intermuscular and subcutaneous, the other 13% are perinephric and retroperitoneal fat. The composition of deposited fatty acids depends on the age and weight of the animal as well as the length of the post weaning period. The sex and fattening level will also affect the fatty acid composition (Bas & Morand-Fehr, 2000).

In South Africa, the mutton classification system is used to describe lamb and mutton according to tissue composition and potential eating quality (tenderness) of the carcasses. Sheep carcasses in South Africa is therefore classified by the National Department of Agricultural Product Standards Act, ACT No. 119 of 1990, and its regulations and are based on four age groups (Table 1) and furthermore on seven fat classes (Table 2) (SAMIC, s.a.).

TABLE 1: Age classification of sheep carcasses (SAMIC, s.a.)

Age	Classification
0 Incisors	A
1 – 2 Incisors	AB
3 – 6 Incisors	B
More than 6 Incisors	C

According to the fatness classification of sheep, (National Department of Agriculture, 1990), the seven fat classes are described as follows in Table 2:

TABLE 2: Fatness classification of sheep carcasses (SAMIC, s.a.)

Fatness	Guideline for the determination of	Guideline for the percentage
0	Zero	Less than 1.0
1	Less than one	Not more than 5.6
2	At least 1 but not more than 4	> 5.6, but not more than 8.6
3	More than 4 but not more than 7	> 8.6, but not more than 11.6
4	More than 7 but not more than 9	> 11.6, but not more than 14.6
5	More than 9 but not more than 11	> 14.6, but not more than 17.6
6	More than 11	> 17.6

A sheep carcass contains a small amount of fat at birth, and the fat increases slowly until the fattening phase sets in and fat is deposited at an increasing rate (Berg & Butterfield, 1978). Fat is the most variable tissue in the carcass and also the most important factor influencing the carcass composition thus the slaughter weight should correspond with the point of maturity where the fat levels are optimal (Berg & Butterfield, 1978).

MATERIALS AND METHODS

Sampling

Eighteen mutton carcasses (9 Dorper and 9 Merino) of the C age and fatness class two were used in this study (Table 3). The carcasses originated from three different mutton producing regions (Karoo, Kalahari and Ermelo) (Figure 1) in South Africa and the carcasses were obtained from large abattoirs from these selected areas. Carcasses had been classified by quality classifiers. Commercial slaughtering and dressing procedures were followed. The kidneys were removed and weighed for each carcass. On the day after slaughter, the chilled carcasses were sectioned down the vertebral column by band saw and transported to Irene ARC:LBD where physical dissection continued the following day.

TABLE 3: Experimental design for evaluation of carcass and chemical composition of South African mutton (C2)

Class	Breeds (n=2)	Area (n=3)
C2	Dorper (n=9)	Karoo (n=3)
		Kalahari (n=3)
		Ermelo (n=3)
	Merino (n=9)	Karoo (n=3)
		Kalahari (n=3)
		Ermelo (n=3)
	Total carcasses = 18	

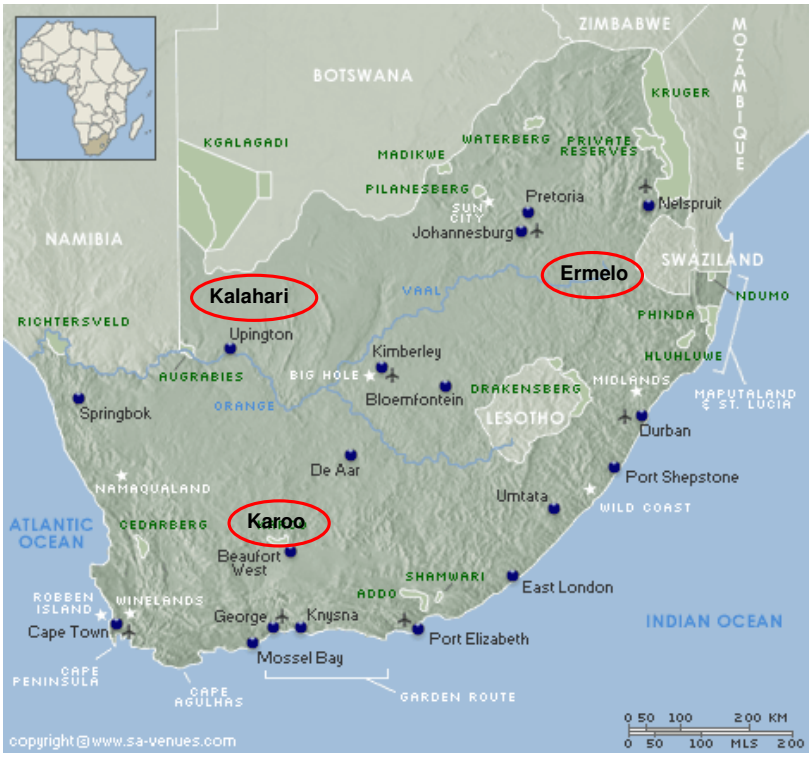

FIGURE 1: Map of carcass origin (sa-venues, s.a)

Physical dissection

Carcasses were weighed prior to being halved and sub-divided into the respective primal cuts. A trained deboning team was responsible for the physical dissection of the cuts after the carcasses were sectioned down the vertebral column with a band saw, and then subdivided into the following 10 primal cuts (Figure 2): neck, thick rib, flank, shoulder, breast, rib, loin, chump, leg and shins (front shin and hind shin were analysed together). For each cut of the right sides of the carcasses, the % meat (muscle + intramuscular fat), subcutaneous fat and bone content were determined, in order to calculate carcass composition. Therefore the cuts were divided into three parts namely meat (muscle + intramuscular fat), fat (intermuscular + subcutaneous fat) and bone, in an environmentally controlled abattoir at 6ºC by a trained de-boning team. The primal cuts of the left sides of the carcasses were vacuum packed and frozen till required for cooked analysis. Meat, fat and bone were expressed as a percentage of the carcass side's weight (without the kidney fat) and of the relevant cut.

Dissection forms were used to record the weight of meat, fat and bone (Appendix A). These values were used to calculate the cut composition and carcass composition.

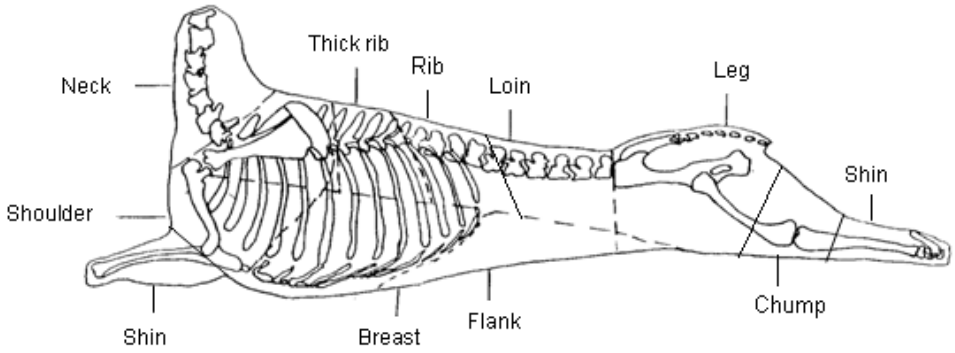

FIGURE 2: Dissection diagramme (Casey, 1982)

Three cuts (leg, loin and shoulder), representing the most expensive and sought after cuts, taken from both sides, were used to determine the cooked (left side) and raw (right side) nutrient composition. The three cuts, from the left sides used for the cooked analysis, were vacuum packed and frozen for two months at - 20 ℃ until the cooking process commenced. The three cuts (leg loin and shoulder) were defrosted for 24 hours and cooked according to standardised moist or dry heat cooking methods in identical Mielé ovens at 163℃ to an internal temperature of 73℃ measured in the geometrical centre of the cut (American Meat Science Association, 1995). Cooking losses were measured for both cooking methods (dry and moist) as part of the standard procedure. After cooling down, the cuts were weighed and then dissected into meat (muscle + intramuscular fat), fat (subcutaneous + intermuscular fat) and bone. The meat and fat from the raw and cooked cuts respectively of a single carcass were combined. After cubing, it was thoroughly mixed and then minced first through a 5mm and then through a plate with 3mm diameter holes. Samples of 300g meat and separable fat were put into a vacuum bag prior to being freeze-dried and sent to the ARC Analytical Laboratory at Irene for proximate analysis. The analytical procedures for proximate analysis of the mutton samples were done on a double blind basis in laboratories that form part of the South African National Accreditation Services (SANAS).

The raw and cooked nutrient data of the three cuts was compared based on the assumption, (Kirton, Barton & Rae, 1962) that the chemical composition of the two sides is similar or almost identical.

Analysis

Carcass composition was calculated using the dissection results (meat (muscle + intramuscular fat), fat (subcutaneous fat + intermuscular) and bone) of each of the ten cuts. The muscle weights of each of the ten cuts were added to calculate the carcass muscle. The fat and bone masses were calculated similarly.

Statistical analysis

Data was statistically analysed using the GenStat for Windows (2000) statistical computer program. The significance of the variables, meat, fat, bone and regions as well as breeds measured for each sample, was tested by means of a one - way analysis of variance (ANOVA) (unbalanced block design). If a main effect was significant, the Fisher's protected t-test Least Significant Difference (LSD) was applied to determine the direction of the differences between the mean values (Snedecor & Cochran, 1980).

RESULTS AND DISCUSSION

Physical content of Dorper and Merino carcasses

Carcass weight together with fat content, sex, age and cut are important factors in the grading system of carcasses (Abdullah & Qudsieh, 2008). Although consumers prefer to buy lighter carcasses, it is not justified on the basis of meat quality (Abdullah & Qudsieh, 2008). The average carcass weights for South African mutton are 10.46kg per side (Table 4).

South African mutton carcasses contained higher amounts of intermuscular fat (9.16%) than subcutaneous fat (7.78%). Van Heerden (2007) reported that South African lamb (A2) contains similar percentages of subcutaneous fat (7.45%). The levels of subcutaneous fat found in the South African carcasses are very low compared to a study done in the United Kingdom (UK) in 1987, stating that 26% of the average sheep carcass consists of separable fat (Kempster *et al*., 1987). More than 63% of the carcasses consisted of lean muscle and an average of 20% of the carcass consisted of bone.

TABLE 4: Means for carcass and cut composition of South African mutton (C2) carcasses

Attribute	Unit	C2
Carcass weight (only left side)	kg	10.46
Mean weight of each cut:		
Neck	g	1182
Thick rib		810
Flank		720
Shoulder		1537
Breast		1430
Rib		711
Loin		1006
Chump		953
Leg		2308
Shin		907
Carcass composition (% of carcass weight less the kidney plus fat)		
Meat (lean) (muscle + intramuscular fat)	%	63.2
Bone	%	20.5
Fat	%	16.9
Subcutaneous fat		*7.78*
Intermuscular fat		*9.16*
Total		100.6

Physical content of the carcass and respective primal cuts for South African mutton (C2)

Results of the study showed that lean muscle was the only trait that differed significantly between the physical composition of the ten primal cuts (Table 5), with the rib cut containing the lowest amount of lean muscle and the leg cut containing the highest amounts of lean muscle. These results are supported by Tschirhart-Hoelscher, Baird, King, McKenna and Savell (2006) who concluded that lean muscle content varies greatly among the different cuts due to different muscle sizes in the different cuts. According to Kempster (1980) relative growth of subcutaneous fat in the loin, breast and neck of C2 mutton was higher than in the total carcass, while that of the shoulder and leg was lower. For the loin, leg and shoulder cuts this was in agreement with the present study, however, Kempster (1980) did not report on the flank. Adipose deposits strongly influence the quality of the ruminant carcass, not only by amount, but also the composition (Bas & Morand-Fehr, 2000). Genetic differences may also influence the fat deposition as some breeds begin to fatten at lighter weight than other breeds (Berg & Butterfield, 1978).

TABLE 5: Calculated physical composition (% of cut weight) of the ten primal cuts of South African mutton

Traits	Unit	Neck	Thick rib	Flank	Shoulder	Breast	Rib	Loin	Chump	Leg	Shin
Bone	%	20.4	26.5	0.6	17.3	25.0	23.7	17.8	17.0	13.4	42.0
Meat (Muscle + intra muscular fat)	%	62.8	61.6	70.0	70.7	49.4	52.5	65.5	64.2	76.4	54.5
Inter muscular fat	%	13.2	10.4	15.0	6.3	15.5	11.6	6.6	7.8	3.8	1.2
Subcutaneous fat	%	3.6	1.5	14.4	5.6	10.0	11.0	10.0	11.0	6.4	2.3

Carcass composition expressed as percentage of carcass weight is a good indication of the physical composition as it gives one an immediate indication of fat and muscle percentages of the whole carcass (Table 6). Upon comparing the results from the percentage physical composition of the current study with results from the literature (Kempster *et al*., 1987) it is obvious that results from the current study indicate that South African mutton contains 46.8% less fat and 28% more lean muscle than previously determined by Kempster *et al*. (1987).

TABLE 6: A comparison of mutton carcass composition between SA and previously published data in the UK

	Unit	Mutton (C2) [1]	Mutton (C2) [2]
Bone	%	15	21
Lean muscle	%	53	63
Total Fat	%	32	17

[1] Kempster *et al*., 1987
[2] Current study

The physical composition of each cut differs dramatically due to the growth patterns and maturity stages of the animals. As seen in Table 5, the shin contains, as expected the highest quantity of bone and lowest fat content of all the cuts. The thick rib and neck cuts contain low amounts of subcutaneous fat but contain more than 10% intermuscular fat. According to Abdullah and Qudsieh (2008) the core of the carcass, which is approximately at the loin and thick rib region, is the part that matures last thus explaining the lower levels of subcutaneous fat in the thick rib cuts. The leg, flank and shoulder cuts are the cuts that contained the highest amount of lean muscle of all ten cuts. According to Abdullah and Qudsieh (2008) the leg and shoulder cuts are higher in muscle due to the growth patterns of animals, whereas the relative growth in limbs is higher. The flank cut furthermore contained only 0.6% bone on average compared to the 20.5% average bone content in the carcass. The same trend was apparent in the study done on the physical composition of South African lamb

(A2) where the average bone content of the flank was 1.7% (Van Heerden, 2007). In agreement with the study done on South African lambs (Van Heerden, 2007) the flank furthermore contained the highest amounts of subcutaneous fat when compared to the other cuts.

Differences in physical composition between Dorper and Merino carcasses

According to Hopkins (1996) physical composition differences between breeds are common as some breeds invariably have a poor body conformation. Webb and Casey (1995) state that Dorper breeds mature earlier than Merino breeds, and this can explain the differences in carcass composition between the two breeds. The difference between the ten wholesale cuts when comparing the Dorper and Merino carcasses (Table 7) is small, and only five cuts differed significantly on one trait. The bone content of the neck (193.7g and 272.4g) and the rib cut (141.3g and 198.0g) differed significantly between the two breeds; with the Merino breed having higher bone content for both cuts. The lean meat (muscle + intramuscular fat) of the shin, shoulder and thick rib cuts differed significantly between the two breeds with the Merino breed containing higher amounts of lean muscle in all three cuts. There was a significant difference between the bone content of six cuts. For all six cuts, the bone content of the Merino breed was significantly higher than that of the Dorper breed. Seven cuts from the Merino breed contained a significantly higher lean mass when compared to the lean mass from the Dorper. The same trend, indicating that Merino carcasses contain higher amounts of lean muscle and bone, was found in a study conducted on the carcass composition of South African lamb (A2) (Van Heerden, 2007). However, greater differences between the Dorper and Merino breeds were apparent in that specific study. Although no significant differences were found between the fat content of the two breeds, Kempster (1980) noted that the largest difference between sheep breeds is the variation in the portioning of fat between fat depots.

TABLE 7: Meat (lean + intramuscular fat), fat and bone content of individual cuts of South African C2 Dorper and Merino mutton

Cut	Traits	p-value	Unit	SEM	Mean	
					Dorper	Merino
Neck	Lean	0.021	g	65.7	601.0	851.0
	Inter-Fat	0.521	g	21.7	135.0	155.0
	Sub Fat	0.074	g	13.22	25.1	61.9
	Bone	0.002	g	14.09	193.7	272.4
Thick rib	Lean	0.001	g	23.3	418.0	558.0
	Inter-Fat	0.017	g	7.69	64.9	95.5
	Sub Fat	0.984	g	5.65	12.4	12.6
	Bone	0.006	g	10.22	187.4	237.1
Flank	Lean	0.223	g	26.9	518.0	469.0
	Inter-Fat	0.269	g	26.5	94.0	138.0
	Sub Fat	0.284	g	18.3	113.0	82.0
	Bone	0.327	g	3.22	1.7	6.3
Shoulder	Lean	0.001	g	39.0	966.0	1198.0
	Inter-Fat	0.169	g	19.7	79.0	120.0
	Sub Fat	0.202	g	14.3	72.0	99.0
	Bone	0.033	g	9.8	245.7	279.1
Breast	Lean	0.944	g	37.0	692.0	695.0
	Inter-Fat	0.185	g	45.3	185.0	276.0
	Sub Fat	0.590	g	22.7	141.0	123.0
	Bone	0.353	g	15.7	337.0	359.0
Rib	Lean	0.008	g	17.5	328.0	408.0
	Inter-Fat	0.064	g	14.9	62.0	105.0
	Sub Fat	0.871	g	9.48	82.7	80.4
	Bone	<0.001	g	8.94	141.3	198.0
Loin	Lean	0.010	g	29.0	587.0	712.0
	Inter-Fat	0.005	g	9.62	46.7	94.0
	Sub fat	0.421	g	17.4	87.0	107.0
	Bone	0.132	g	21.5	156.0	205.0
Chump	Lean	0.157	g	28.4	573.0	634.0
	Inter-Fat	0.021	g	5.66	61.0	82.4
	Sub fat	0.066	g	10.9	88.1	119.6
	Bone	0.163	g	7.70	150.1	166.4
Leg	Lean	0.046	g	61.0	1659.0	1851.0
	Inter-Fat	0.455	g	10.68	83.0	94.7
	Sub Fat	0.096	g	11.30	131.9	160.8
	Bone	0.020	g	9.80	290.3	327.6
Shin	Lean	<0.001	g	18.7	435.0	553.0
	Inter-Fat	0.669	g	5.21	9.7.0	12.9
	Sub Fat	0.281	g	5.99	16.2	25.8
	Bone	0.006	g	12.80	345.7	406.4

p-value≤0.05 indicate significant differences

Upon comparing the physical composition of the ten wholesale cuts for three mutton producing areas (Ermelo, Kalahari and Karoo) in South Africa (Table 8), significant differences were mainly found in the bone content of the C2 mutton from different regions. A significant difference was apparent in the bone content of the neck, thick rib, breast, rib and leg. In all five cuts the bone content of the Ermelo mutton was significantly less than the bone content of the Kalahari mutton.

TABLE 8: Meat (lean), fat and bone content of individual cuts of South African mutton (C2) from three regions

Cut	Traits	p-value	SEM	Ermelo	Kalahari	Karoo
Neck	Lean	0.109	80.4	592	858	727
	Inter-Fat	0.052	26.6	121	108	205
	Sub Fat	0.990	16.19	41.8	45.1	43.7
	Bone	0.005	17.26	196[a]	291[b]	212[a]
Thick rib	Lean	0.207	28.5	467	532	465
	Inter-Fat	0.135	9.42	80.2	65.6	94.8
	Sub Fat	0.617	6.93	16.8	13.6	7.2
	Bone	0.003	12.52	204[a]	256[b]	176[a]
Flank	Lean	0.005	32.9	488	397	595
	Inter-Fat	0.028	32.5	92[a]	58[a]	198[b]
	Sub Fat	0.905	22.4	90	104	99
	Bone	0.283	3.94	9.3	0.5	2.2
Shoulder	Lean	0.020	47.7	971[a]	1196[b]	1080[ab]
	Inter-Fat	0.641	24.1	84	117	98
	Sub Fat	0.490	17.5	69	89	99
	Bone	0.133	12.01	241	270	276
Breast	Lean	0.053	21.5	45.3	619	669
	Inter-Fat	0.283	55.5	170	212	309
	Sub Fat	0.598	27.8	153	113	129
	Bone	0.014	19.3	295[a]	359[b]	390[b]
Rib	Lean	0.009	21.5	316[a]	432[b]	358[a]
	Inter-Fat	0.564	18.3	72	99	80
	Sub Fat	0.336	11.62	66.8	89.3	88.5
	Bone	<0.001	10.94	158[a]	220[b]	132[a]
Loin	Lean	0.133	35.5	587	673	689
	Inter-Fat	0.061	11.79	57.0	96.0	58.0
	Sub fat	0.635	21.4	81	101	109
	Bone	0.676	26.3	165	198	178
Chump	Lean	0.097	34.7	540	658	612
	Inter-Fat	0.354	6.93	75.7	63.2	76.3
	Sub fat	0.552	13.34	98.5	116	97.0
	Bone	0.367	9.43	169	149	158
Leg	Lean	0.233	74.7	1648	1932	1786
	Inter-Fat	0.030	13.08	60.2[a]	89.2[ab]	117.2[b]
	Sub Fat	0.501	13.84	133	153	153
	Bone	0.024	12.01	278[a]	330[b]	319[b]
Shin	Lean	0.010	22.9	424[a]	525[b]	532[b]
	Inter-Fat	0.452	6.38	4.8	16.3	12.7
	Sub Fat	0.322	13.84	133	15	15
	Bone	0.074	15.67	346	381	402

p-value≤0.05 indicate significant differences).
Means with different letters (a, b or c) are significantly different

The carcass composition of South African lambs (A2) from these three different regions (Van Heerden, 2007) differs from the C2 results. The A2 flank and leg cut from the Karoo region contained a higher content of intermuscular fat and the bone content of the breast cut were significantly higher than in the other regions. According to Bas and Morand-Fehr (2000) these differences are evident in lambs and mutton and could be attributed to the length of post weaning. The composition of deposited fatty acids depends on the age and weight of the animal thus explaining these smaller differences between the mutton carcasses of age class C.

Chemical composition of the raw and cooked South African mutton (C2 carcasses)

Changes in the chemical composition of mutton during the cooking process are apparent in Table 9. During the cooking process, 13% of the moisture present in 100g mutton (C2) muscle is lost. This decrease in moisture leads to the increased concentrations of protein and fat (Jamora & Rhee, 1998). On average the muscle of the cooked mutton cuts contained 6.2g more protein and 3.72g more fat than the raw muscle from the same cuts. According to Webb and O'Neil (2008) the fat present in meat contributes to the eating quality of meat as it notably influences the quality of the tenderness and flavour. The importance of fat on meat quality was also emphasised by Juarez, Horcada, Alcade, Valera, Mullen & Molina, 2007. Webb and O'Neil (2008) accentuate the importance of focusing on the global importance of carcass fat to the producer, processor and consumer. The processor's ability to disassociate fatness from muscling further limits the strengths relationship between lean carcass and conformation (Kempster *et al.*, 1987).

TABLE 9: Means for the chemical composition of 100g meat (containing intramuscular fat) of C2 mutton carcasses

		C 2 mutton	
Proximate Analysis	Unit	Raw	Cooked
Moisture	g	73.81	63.99
Protein (Nx6.25)	g	20.15	26.30
Fat	g	4.86	8.58
Ash	g	1.18	1.13

According to Schönfeldt and Gibson (2008) there is a worldwide demand for high-value animal protein, and this demand is growing daily. With 26.3% of cooked muscle from mutton (C2) consisting of protein, South African mutton (C2) is an excellent source of protein.

Upon comparing the chemical composition of the three selected cuts in the raw and cooked state respectively (Table 10), it is apparent that the fat and ash content didn't change significantly during the cooking process. The moisture and protein content differed significantly for each of the three cuts between the raw and the cooked state. According to Jamora and Rhee (1998), the decrease in moisture during the cooking process is the main factor leading to increased protein content.

TABLE 10: Means for the chemical composition of 100g meat (containing intramuscular fat) of three selected cuts of 18 class C2 mutton carcasses

Proximate analysis	p - value	SEM	Unit	Raw			Cooked		
				Leg	Loin	Shoulder	Leg	Loin	Shoulder
Moisture	0.001	0.505	g	74.74[c]	73.71[c]	73.29[c]	63.39[a]	62.73[a]	65.83[b]
Protein (Nx6.25)	0.003	0.389	g	20.48[a]	20.39[a]	19.86[a]	28.14[d]	26.31[c]	24.42[b]
Fat	0.053	0.386	g	3.84	4.96	5.79	7.20	9.80	8.74
Ash	0.124	0.0473	g	1.208	1.182	1.158	1.073	1.085	1.215

p-value≤0.05 indicate significant differences.
Means with different letters (a, b or c) are significantly different

CONCLUSION

Due to the increased focus and consumer demand for lean meat, the eating quality of meat has become a focus point in the meat industry. This demand emphasises the importance of physical composition data for all meat carcasses as well as the respective cuts. This study on the physical composition of the South African mutton carcass indicates that 63.2% of the carcass consists of muscle, and fat contributing 16.9% to the total carcass composition. South African mutton carcasses contained higher amounts of intermuscular fat (9.16%) than subcutaneous fat (7.78%). Of the total fat content, 54% consisted of intermuscular fat. The levels of subcutaneous fat found in the South African carcasses are very low compared to a study done in the UK in 1987, stating that 26% of the average sheep carcass consists of separable fat (Kempster *et al.*, 1987). On average, 20% of the carcass consisted of bone. Comparing the current result with the published data (Kempster *et al.*, 1987), it is clear that there are significant differences between South African mutton (C2) and that of the UK.

Physical composition differences between breeds are common as some breeds invariably have a poor body conformation (Hopkins, 1996) or mature at different stages (Webb & Casey, 1995). When comparing the Dorper and Merino carcass the difference between the ten wholesale cuts is small and only five cuts differed significantly for one trait. No significant differences in the composition of the ten wholesale cuts were found either between the three different regions included in this study, contradicting literature explaining that body conformation changes to adapt to climate changes (Abdullah & Qudsieh, 2008).

Evaluating the physical composition of the 10 wholesale cuts of South African mutton (C2), it is comprehensible that the same trend was apparent as in the study done on the physical composition of South African lamb (A2). In both studies the average bone content of flank was 1.7% (Van Heerden, 2007) and the flank furthermore contained the highest amounts of subcutaneous fat when compared to the other cuts. In further agreement with the study done on South African lambs (Van Heerden, 2007) the Merino carcasses were heavier and on average the different traits for each cut of

the Merino breed was higher than for the Dorper breed. Thus the trends appear to be from the results of the current study in physical composition of South African mutton (C2) and South African lamb (A2) (Van Heerden, 2007). Therefore it can be concluded that C2 South African mutton contains less fat than previously used UK physical composition data indicated.

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THE NUTRIENT COMPOSITION OF SOUTH AFRICAN MUTTON (C2 CLASS)

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ABSTRACT

Dorper and Mutton Merino carcasses of the C age group with a fat code 2 (± 7% SCF) from three main production areas (Karoo, Kalahari and Ermelo) in South Africa were analysed for nutrient composition in this study. The **right** sides of the carcasses were used to determine the nutrient and physical (carcass) composition of each raw cut as well as the whole carcass by calculation. Three cuts (loin, leg and shoulder) from the left side were cooked in order to determine the nutrient composition thereof. Cooking resulted in an increase in the protein and cholesterol concentrations of the cooked cuts. Iron content was higher in the cooked loin and leg but decreased in the cooked shoulder. According to nutrient density, mutton is a good source of protein, iron and B vitamins and supplies more than 25% of RDA/100g of vitamin B_{12} when cooked. A 100g edible portion of the leg, loin and shoulder has a nutrient density higher than the one for protein, iron, zinc and vitamin B_{12} indicating that these cuts are a good source of the specific nutrients. A 100g edible portion of the loin cut contained higher fat quantities (13.2g) than the cooked shoulder (11.7g) and leg (9.91g). The loin cut also had a higher cholesterol content (70.8mg) compared to the cholesterol content in the shoulder (58.5mg) and leg (57.9mg).

Key Words: Nutrient composition, South Africa, Mutton, Nutrition, Dorper, Merino

INTRODUCTION

Nutrition plays an integral role in the optimal functioning of the body compared to malnutrition (including under-nutrition and over-nutrition) that is a health impairment resulting from a deficiency,

excess or imbalance of nutrients (Robinson, 1978). Most developing countries are faced with the double burden of persisting under-nutrition as well as the growing epidemic of obesity and non-communicable diseases such as cancer and heart disease and South Africa is no exception (Labadarios & Oelofse, 2000). Information to link nutrition and chronic diseases is necessary to inform the consumer on healthier food choices. This information will help the consumer to make educated and informed changes to their diet. Meat is a nutrient dense food and contributes various essential nutrients to the body that are needed for normal and optimal growth and functioning of the immune system and general metabolism of substrates (Badiani, Nanni, Gatta, Bitossi, Tolomelli & Manfredini, 1998; Enser, 2000). Despite the associated benefits, red meat is frequently associated with a negative health image as it contains fat (Biesalski, 2005). Although high fat intake is associated with increased risk of coronary heart diseases, obesity and cancer, meat is an excellent source of protein, essential fatty acids, oleic and linoleic acid as well as minerals such as iron, zinc and phosphorous and the B-vitamins (Badiani *et al*., 1998). Cosgrove, Flynn and Kiely (2005) explain that the reason why diets high in red meat are associated with increased risks of coronary heart diseases, diabetes and obesity, the fact remains that high protein diets usually contain low amounts of vitamin C and fiber. Thus it can be assumed that the negative health image should not be connected to the intake of red meat, but rather the absence of fibre and vitamin C.

The bioavailability of folate and iron found in red meat is higher and thus more readily absorbed than these minerals from plant sources (Biesalski, 2005). Meat is the only available natural source of retinol and vitamin B_{12} and vegetarians can therefore easily develop vitamin B_{12} deficiencies due to restricted animal product consumption (Koebnick, Hoffmann, Dagnelie, Heins, Wickramasinghe, Ratnayaka, Gruendel, Lindermans & Leitzman, 2004). Red meat contains high amounts of protein and low quantities of carbohydrates which translate into a low glycemic index, making it an ideal food for overweight and diabetic persons (Biesalski, 2005).

The commercial sheep industry competes with other animal proteins such as beef, pork, poultry and fish as an affordable product to the consumer, who has many other choices of high quality meat. In this competitive environment, the sheep industry must monitor and react to the changing preferences of the consumer. This could be achieved in part by the production of uniform, safe, nutritious and lean mutton products (Shackelford, Leymaster, Wheeler & Koohmaraie, 2003). Table 1 illustrates the nutritional differences between mutton (as currently published in South African food composition tables), beef and pork, values that can be used in the competitive marketing industry.

TABLE 1: Comparison of the nutrient content of raw mutton, beef and pork (Sayed, Frans & Schönfeldt, 1999).

Nutrients	Unit	Mutton	Beef	Pork
		Raw	Raw, age	Raw
Moisture	g	60.7	60.7	49.8
Energy	kJ	1087	1057	1535
Protein	g	16.9	18.4	13.9
Fat	g	21.6	20.1	35.1
Cholesterol	mg	72	62	74
Saturated fatty acids	g	9.47	9.19	12.44
Mono-unsaturated fatty acids	g	8.86	8.94	15.93
Poly-unsaturated fatty acids	g	1.7	0.28	3.8
Iron	mg	1.6	1.9	0.7
Zinc	mg	3.33	3.53	1.59

According to the data in Table 1, the protein content of mutton is similar to beef and pork. However when compared to the digestibility of plant proteins, mutton proteins are better digestible (Biesalski, 2005). The total fat content of mutton is similar to beef but 38.5% less than pork. Red meat in general is an excellent source of minerals and B-vitamins and provides bioavailable iron to the body. Mutton and beef contain high amounts of minerals, especially zinc and iron.

Mutton is not consumed as often as other red meat as South African consumers have the perception that mutton is high in fat and expensive. It is mainly seen as luxury food for special occasions. Badiani *et al*. (1998) reported that consumers in Italy prefer consuming meat of younger lambs and to lesser extent older larger carcasses. It is based on the belief that meat from older and heavier animals is of poor quality.

Although high intakes of some animal products are associated with increased fat consumption and may lead to gaining weight (Givens, 2005), Enser (2000) emphasise the numerous nutritional benefits associated with meat. It is proposed that fat associated with the consumption of red meat may increase the risk for colon cancer as it promotes the excretion of bile which can be converted to carcinogens (Biesalksi, 2005). Nevertheless, red meat holds numerous beneficial benefits for the human body.

The amount of fat in the carcass and muscle influences the fatty acid composition and thus the healthfulness of the meat (Wood, Richardson, Nute, Fisher, Campo, Kasapidou, Sheard & Enser, 2003). The fatty acid composition of muscle affects the oxidative stability during processing as the polyunsaturated components are responsible for oxidative breakdown (Wood *et al*., 2003). The fatty acid composition of ruminant meat differs from that of non-ruminants. Ruminant fat tissue contains higher percentages of saturated fatty acids and thus is firmer. A study conducted in the United

Kingdom (UK) concluded that age also affects the fat content of ruminants because the fat content increases when the animal ages (Wood *et al*., 2003). As the body fat increases, the overall fatty acid composition changes and neutral lipid predominates. Fat of ruminants that are excessively fat may be softer as the unsaturated fatty acids content is higher and thus the melting point is lower (Wood *et al*., 2003). Wood *et al.* (2003) further explains that fat from grain-fed ruminants is softer as it contains lower concentrations of saturated fatty acids. The ratio of polyunsaturated to saturated fatty acids (P:S ratio) is lower in ruminants compared to non-ruminants, because most unsaturated fatty acids are hydrogenated in the rumen and only small quantities are deposited in the body fat (Enser, Hallet, Hewett, Fursey, Wood & Harrington, 1998). According to Wood *et al.* (2003) higher P:S ratios are more advantageous to a person's health as a high content of saturated fatty acids is connected to a negative health image. The n-6: n-3 ratio (Table 2) on the other hand is lower in ruminant meat. The high content of n-3 PUFA (a trans fatty acid) which contribute beneficially to optimal health (Enser, 1998) is associated with the presence of α-linolenic acid (18:3) present in the grass (Wood *et al*., 2003). The fatty acid composition of red meat plays an integral role as it differs drastically between sheep, cattle and pigs (Table 2) and the correct composition is associated with healthier meat (Wood *et al*., 2008).

TABLE 2: Fatty acid composition of fat and muscle of whole steak from cattle, sheep and pork (adapted from Wood *et al.,* 2003)

Fatty acids		**Cattle**	**Sheep**	**Pig**
16:0 Palmitic	Fat	26.1	21.9	23.9
	Muscle	25.0	22.2	23.2
18:0 Stearic	Fat	21.2	22.6	12.8
	Muscle	13.4	18.1	12.2
18:1 n-9 Oleic	Fat	35.3	28.7	35.8
	Muscle	36.1	32.5	32.8
18:2 n-6 linoleic	Fat	1.1	1.3	14.3
	Muscle	2.4	2.7	14.2
18:3 n-3 α-linolenic	Fat	0.48	0.97	1.43
	Muscle	0.7	1.37	0.95
P:S		0.11	0.15	0.58
n-6:n-3		2.11	1.32	7.22

Ruminant fat naturally contains the fatty acid Conjugated Linoleic Acid (CLA) with beneficial pharmacological activity. These beneficial effects associated with CLA counteract the effects of the trans unsaturated fatty acids found in ruminant fat (Enser, 2000).

CLA refers to a group of isomers, positional and geometrical, of the unsaturated fatty acid linoleic acid (C18) that contains two double bonds which are separated with one single bond (Fritsche, J., Fritsche, S., Solomon, Mossoba, Yurawecz, Morehouse & Ku, 2000). Each double bond can either be in the *cis* or *trans* configuration, therefore many forms of CLA are possible with the main form found in food being *cis*-9, *trans*-11 (Figure 1) (McGuire & McGuire, 1999) and *trans*-10, *cis*-12 (Figure 2) (Park & Pariza, 2006). Bhattacharya, Banu, Rahman, Causey and Fernandes (2006) confirmed that these two

isomers are the two main CLA isomers naturally found in ruminant meat with 80-90% of all CLA found in the *cis*-9, *trans-11* form.

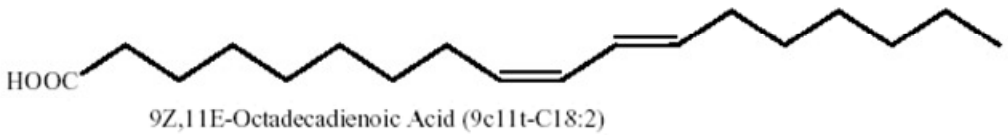

FIGURE 1: The *cis*-9, *trans*-11 CLA isomer (Schmid, Collomb, Sieber & Bee, 2006)

CLA occurs naturally in ruminants and is formed by a bacterial isomerase in the rumen as the first stage in the biohydrogenation of linoleic acid to stearic acid (Enser, 2000). The CLA isomer commonly found in lamb and mutton, *cis*-9, *trans*-11 (Figure 1), was recently given the trivial name rumenic acid as this fatty acid is produced in the rumen of animals (McGuire & McGuire, 1999).

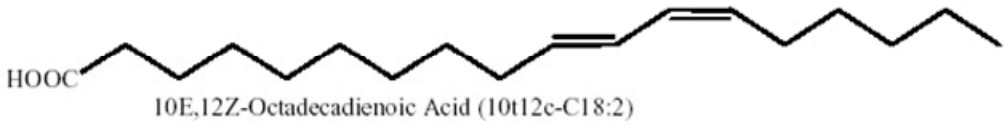

FIGURE 2: The *trans*-10, *cis*-12 CLA isomer (Schmid *et al*., 2006)

Already in 1985, Pariza and Hargraves discovered that CLA found in meat has anti-mutagenic activities. CLA isomers appear to modulate cancer, body composition, body weight, immune function and glucose metabolism in experimental models (Whigham, Cook & Atkinson, 2000). Most of South African sheep and lambs are raised in open fields and on pastures where they feed of the grass and shrubs. As grass contains high amounts of Conjugated Linoleic Acid (CLA), it is proposed that the meat produced on this will also contain high amounts of CLA (McGuire & McGuire, 1999; Riserus, Bergland & Vessby, 2001).

Consumers are becoming more health conscious and are increasingly focusing on food safety as well as their eating habits and nutrient intake (Garnier, Klont & Plastow, 2002). The consumers' involvement influences the whole food chain, agriculture and science (Garnier *et al*., 2002). Food choices can have a positive or negative influence on the person's health status (Kruger, Van der Spuy & Viljoen, 2003). Some diseases commonly found in South Africa are related to malnutrition (under- and overnutrition), thus emphasising the need for greater knowledge on the composition of food (Johnson, 1987). Detailed knowledge on the composition of foods is essential to understand the function of nutrients in the diet. The assessment of dietary exposure is critical for the interpretation of the relationship between nutrition and health (Deharveng, Charrondiere, Slimani, Southgate & Riboli,

1999). Therefore food composition tables give information on the portion, composite sample, collection and analysis of the composition of foods (Miller & Payne, 1961; Southgate, 1998) and can be used to evaluate a person's food intake and compare it to the Recommended Dietary Allowance (RDA) (Whitney & Rolfes, 2002).

Many countries use one national food composition table that contains food commonly eaten in the country. Some of the data analysed in one country is also used in the food composition tables of other countries. Problems arise where the different countries use different methods to analyse nutritional composition as well as different measuring units and cooking methods. Due to difference in definitions, methods and methods of analysis it is obvious that these food composition tables are not internationally applicable and it is therefore important that each country has their own food composition tables (Deharveng *et al*., 1999). Food composition tables for South African foods were compiled by the Research Institute for Nutritional Diseases (NRIND) in 1991 (Langenhoven, Kruger, Gouws & Faber, 1993). Current South African food composition tables are compiled by the Medical Research Council (MRC) (Langenhoven *et al*., 1993). However, only 41% of the data in these tables is currently derived from South African foodstuffs (Sayed *et al*., 1999) with the remaining data obtained mainly from American and English food composition tables.

Previous nutrition data on mutton for South African food composition tables was borrowed from the UK food composition tables (Langenhoven *et al*., 1991) but the latest update on mutton and lamb that appears in the MRC's food composition tables of 1999 is derived from the United States Department of Agriculture (USDA, 1989) database (Sayed *et al*., 1999). Although sheep in South Africa originated from international breeds the nutritional composition of mutton varies greatly between countries (Table 3) (Van Heerden, Schönfeldt, Kruger & Smith, 2007) due to different reasons, for instance meat products are dissected into different primal cuts in each country, thereby influencing the composition of meat cuts (Schönfeldt, 1998). Amino acids for example differ between different parts of the carcasses and different cutting methods may influence the amino acids detected (Lawrie, 1998). Genetic and environmental factors are the main factors affecting the quality and nutrient content of meat (Okeudo & Moss, 2005). Greenfield and Southgate (2003) further state that differences in climate as well as soil content between the countries may also influence the nutrient content of the animals' feed and thus the nutrient content of the animals' meat. According to Givens (2005) the fatty acid composition of animal products is not fixed and can be altered in response to changes in the diet of the productive animals. Post-mortem factors that differ among countries, such as fat trim levels and cooking can also cause changes in nutrient composition (Jamora & Rhee, 1998). Jamora and Rhee (1998) further explain that cooking leads to moisture loss and thus an increase in concentration of some nutrients and decrease in heat-labile nutrients. The end temperature of the cooking process may have an effect on the moisture content, which can explain the moisture difference between South Africa (SA) and United States of America (USA) values (Table 3).

TABLE 3: Nutrient values in cooked lamb per 100g edible portion for selected countries (adapted from Van Heerden, 2007)

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 half	Cooked leg (shank & sirloin)
		Lean & fat	Lean & fat	90 % meat	Trimmed to ⅛ inch fat	12 % separable fat
		100g	100g	100g	100g	100g
Proximate						
Moisture	g	57.5	67.0	58.7	59.2	63.9
Protein (Nx6.25)	g	25.6	25.8	24.3	29.3	27.7
Fat	g	16.5	16.5	13.3	11.9	7.0
Ash	g	-	-	-	1.1	1.5
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						
Thiamine (B1)	mg	0.1	-	0.2	0.1	0.1
Riboflavin (B2)	mg	0.3	0.3	0.3	0.3	0.5
Niacin (B3)	mg	6.6	6.6	4.5	4.5	7.5
Pyridoxine (B6)	mg	0.2	-	0.2	-	0.1
Cyanocobalamin (B12)	µg	2.6	-	4	-	2.6
Lipids						
Saturated fatty acids (SFA)	g	6.9	6.9	6.1	6.1	3.1
Monounsaturated fatty acids (MUFA)	g	6.9	6.9	5.3	4.3	2.8
Polyunsaturated fatty acids (PUFA)	g	1.1	1.2	0.7	0.2	0.4
Cholesterol	mg	93	93	98	109	100

1 Sayed *et al*. (1999)
2 Gebhardt and Thomas (2002)
3 Chan, Brown, Church and Buss (1996)
4 Lewis, Milligan and Hurt (1995)
5 United Stated Department of Agriculture (1989)
- Value not available

As can be seen in Table 3, the nutritional composition varies among the different countries with great differences in the fatty acid profiles between the countries. According to a study done by Van Heerden *et al*. (2007) it was reported that SA lamb contains on average 40% less fat than that published in the National Food Consumption Tables by the Medical Research Council in 1999. The fat content of lamb in the UK has decreased by 10% over the last twenty years. Therefore the need for nutrient composition data of South African (SA) meat was identified by the Red Meat Producers Organisation (RPO) as a priority.

Generally, the world is consuming less red meat than 40 years ago, therefore it is a priority to analyse the nutrient composition of South African mutton in order to provide the consumer with accurate nutrient composition data and nutrition information (Cobiac, Droulez, Leppard & Lewis, 2003).

MOTIVATION OF STUDY

It is important for countries to have their own nutrient composition data as mutton composition may differ between countries. Countries dissect meat products into different primal cuts thus influencing the composition of meat cuts in each country (Schönfeldt, 1998). Greenfield and Southgate (2003) further stated that differences in climate as well as soil content between the countries may influence the nutrient content of the animals' feed and thus the nutrient content of the animals' meat. Macro-elements in the feed can greatly affect the nutritional quality of the meat (Garnier *et al*., 2002). The fatty acid composition of animal products is not fixed and can be altered in response to changes in the diet of the productive animals (Givens, 2005).

MATERIALS AND METHODS

Sampling

Mutton carcasses from the C age class and fatness level 2 were selected as it represents South African mutton purchased by the consumer. The mutton carcasses were obtained through stratified sampling where food is selected, taking into account the most important causes of variation. Table 4 gives a summarised record of the carcasses (Age class C, fat class 2) used for the study.

TABLE 4: Numbers and locations of C2 mutton carcasses used for the study

Class	Breeds (n=2)	Area (n=3)
C2	Dorper (n=9)	Karoo (n=3)
		Kalahari (n=3)
		Ermelo (n=3)
	Merino (n=9)	Karoo (n=3)
		Kalahari (n=3)
		Ermelo (n=3)
	Total carcasses = 18	

The meat samples, incorporated in the study, comprised of the two most commonly consumed breeds Dorper (n = 9) and Mutton Merino (n = 9) (Van der Westhuizen, personal communication, 2003 in Van Heerden, 2007) carcasses which were obtained from abattoirs that draw mutton from the three main production areas in South Africa namely the Karoo, Kalahari and Ermelo districts. The sheep were slaughtered using standard commercial procedures during four consecutive weeks. The carcasses were classified according to the South African classification system by a qualified classifier at the abattoirs. Selected carcasses were transported in a refrigerated truck (4-6℃) to the Meat Industry Centre of the ARC-LBD, Irene. Upon arrival, all the carcasses were weighed, covered with plastic wrap to prevent moisture loss and chilled at 4℃ overnight and dissected the following day. The

mutton carcasses consisted of the skinned, eviscerated body from which the head, feet, kidney and kidney fat had been removed.

Three cuts (leg, loin and shoulder from the left side of the carcass), representing the most commonly consumed cuts, were used to determine the cooked proximate analysis, physical composition and nutrient composition. These cuts (leg, loin and shoulder) were cooked according to standardized moist and dry heat cooking methods in identical Mielé ovens at 163°C to an internal temperature of 73°C measured in the geometrical centre of the cut (AMSA, 1995). The raw and cooked nutrient data of the three cuts was compared based on the assumption, (Kirton, Barton & Rae, 1962) that the chemical composition of the two sides is similar or almost identical.

Physical dissection

Carcasses were weighed prior to being divided into the respective wholesale cuts. A trained deboning team was responsible for the physical dissection. Carcasses were sectioned down the vertebral column with a band saw, with each side then subdivided into the following 10 primal cuts: neck, thick rib, flank, shoulder, breast, rib, loin, chump, leg and shins. For each cut of the right sides of the carcasses, the % meat, subcutaneous fat and bone content were determined, in order to calculate carcass composition. Therefore the cuts were divided into three parts namely meat (muscle + intramuscular fat), fat and bone, in an environmentally controlled abattoir at 6°C by a trained de-boning team. The wholesale cuts of the left sides of the carcasses were vacuumed packed and frozen till required for cooked analysis.

Proximate analysis

Proximate analysis (fat, moisture, protein, ash) was done on the 10 raw wholesale cuts. Due to limited funding, nutrient analysis was done on only three cooked cuts namely the leg, loin and shoulder cuts. All the raw (n=10 cuts) and cooked (n=3) physical dissected meat (muscle + intramuscular fat) and fat respectively were cubed, thoroughly mixed and then minced first through a 5mm and then through a 3mm mesh plate. 300g sample of meat (muscle + intramuscular fat) and subcutaneous fat respectively were further homogenized with an Ultra Turrax T25 homogenizer after mincing to ensure a proper homogenized sample. Samples were vacuum packed and frozen, prior to being freeze-dried.

Nutrient analysis

Due to limiting funding and in order to comply with the new Draft Regulations (2004) relating (http://www.doh.gov.za/department/dir_foodcontr.html), to the Labelling and Advertising of Foodstuffs as part of the Foodstuffs, Cosmetics and Disinfectants Act, 1972, it is proposed that a composite of three carcasses be pooled and used as a basis of the study. The use of composite samples for analysis rather than individual samples is justified because of funding constraints and has been an accepted approach in food composition studies (Greenfield & Southgate, 2003). Therefore the

samples analysed for this purpose are those of the 3 cuts (leg, loin and shoulder) of the C2 class. However, care was taken in the design to ensure statistical reliability of the data.

A composite sample (3 carcasses of 1 age group, 1 fat code, 2 breeds, and 3 cuts) of raw (left sides) and cooked (right sides) meat (muscle + intramuscular fat) and subcutaneous fat was analysed for nutrient content (Table 5). All foods vary in nutrient composition and its contribution of nutrients to the diet, therefore only the nutrients in meat that are known to be a significant source were analysed at SANAS accredited laboratories. Moisture, ash, fat, vitamin B_1 and B_2, fatty acids and cholesterol were analysed at the ARC analytical laboratory at Irene. Analysis to determine the mineral content was completed at ARC-Institute for Soil, Climate and Water and vitamin B_3, B_6 and B_{12} were analysed at SABS commercial.

TABLE 5: Summary of methods used for nutrient analysis

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)
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 B_3 B_6 B_{12}	 High Performance Liquid Chromatography (HPLC) (Fellman, Artz, Tassinari, Cole, & Augustin, 1992) Official Method 961.14 AOAC (2005) Official Method ALASA 7.2.3 (Strohecker & Henning, s.a) Official Method AOAC 986.23 (2005)
Fatty acid profile and CLA	Gas Chromatography (GC) (Christopherson & Glass, 1969)
Cholesterol	Gas Chromatography (GC) (Smuts, Kruger, Van Jaarsveld, Fincham, Schall, Van Der Merwe & Benadé, 1992)

Statistical analysis

The experiment was designed as a completely randomized design (CRD). Analysis of variance (ANOVA) was used to test for differences between mutton from 3 areas and 2 breeds, as well as the area x breed interaction. The data was acceptably normal with homogeneous treatment variances. Treatment means were separated using Fisher's protected t-test least significant difference (LSD) at the 5% level of significance (Snedecor & Cochran, 1980). Data was analysed using the statistical program GenStat (2003).

Sources of variation for all the nutrient data collected were investigated by ANOVA (GenStat, 2003). For any significant difference found for any variate, the Bonferroni multiple comparison tests were performed. The Bonferroni test is stricter than the ANOVA test, therefore it is not necessarily true that $p \geq 0,05$ will identify differences between means if tested according to the Bonferroni test method.

RESULTS AND DISCUSSION

Nutrient composition for raw and cooked 100g meat portion

In Table 6 the mean values of the nutrient composition for raw and cooked 100g meat (muscle + intramuscular fat) portion of South African C2 mutton are presented. The nutrient values of cooked mutton are more useful to the consumers than raw values (Ono, Berry, Johnson, Russek, Parker, Cahill & Althouse, 1984). However, raw values (Table 6) are used to evaluate production and marketing effects on nutrient composition. Cooked values, on the other hand, provide information on what is actually consumed. The differences in the amount of nutrients between raw and cooked meat cuts can be used to calculate nutrient retention in the cuts (Ono *et al*., 1984).

Examining the nutrient differences between raw and cooked South African mutton meat portions (Table 6), moisture, sodium, thiamine (vitamin B_1) and pyridoxine (vitamin B_6) are the only components that decreased significantly during the cooking process. The notable decrease in thiamine and pyridoxine are probably due to the fact that these vitamins are water-soluble and were lost in the cooking process. The nutrient components protein, fat, riboflavin (vitamin B_2), all fatty acids and cholesterol increased during the cooking process. This concentration in nutrients is mainly due to the moisture loss. Jamora and Rhee (1998) emphasises that cooking leads to moisture loss and thus an increase in concentration of some nutrient and decrease in heat-labile nutrients.

Nutrient composition for raw and cooked 100g fat portion

A significant difference in protein, fat and ash, was apparent between the raw and cooked fat (Table 7). The saturated fatty acid (SFA) content didn't differ significantly between the raw and cooked fat, but monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) content decreased significantly during cooking. Omega 3 (n-3) and Omega 6 (n-6) fatty acids decreased significantly during cooking. The n-6:n-3 ratio is 2.65 for the raw fat and 3.08 for the cooked fat. This ratio in the mutton fat is quite low due to the high n-3 content (Enser *et al*., 1998) compared to the n-6:n-3 ratio in pork (7.22) (Wood *et al*., 2003). The n-3 is associated with the presence of α-linolenic acid present in grass (Wood *et al*., 2003). The P:S ratio of the cooked fat (0.56) is lower than that of the raw fat (0.61). A higher P:S ratio is more advantageous to a person's health as a high saturated fatty acids content is connected to a negative health image.

Nutrient composition for raw and cooked 100g meat portion of Dorper and Merino

The differences between the nutrient components of raw and cooked meat (muscle + intramuscular fat) for the two breeds used in this study (Dorper and Merino) are illustrated in Table 8. Examining the nutrient composition changes during the cooking process for each breed, it is clear from (Table 8) that the differences are minimal. Nutrient components that decrease during the cooking process (Table 8) are similar in the Dorper and Merino breeds. In general, moisture content decreased with cooking, although not significantly so. The cooked meat portion of the Dorper and Merino breeds are low in fat

containing less than 9g fat per 100g cooked meat portion. Looking at the mineral content changes during the cooking process, zinc and iron increases in both breeds while sodium decreases in both breeds. Magnesium and potassium however increases in the Dorper breed during cooking while it decreases in the Merino breed. Vitamin B_1, was the only vitamin that decreased significantly during cooking in the Dorper and Merino breeds. This significant decrease can be due to the moisture loss as vitamin B_1 is a water soluble vitamin (Whitney & Rolfes, 2002). A significant difference was evident for all fatty acids as well as cholesterol content between the raw and cooked mutton (C2) meat.

TABLE 6: Mean values of the nutrient composition for raw and cooked 100g meat (muscle + intramuscular fat, but without subcutaneous fat) portion of South African C2 mutton

Nutrients analysed	Unit	p-value	SEM	Raw (n=18)	Cooked (n=18)
PROXIMATE ANALYSIS:					
Moisture	g	< 0.001	0.287	73.9	64.0
Protein (Nx6.25)	g	<0.001	0.232	20.2	26.3
Fat	g	<0.001	0.219	4.86	8.58
Ash	g	0.162	0.028	1.18	1.12
Food energy	kJ	<0.001	8.63	524	764
MINERALS					
Magnesium (Mg)	mg	0.731	0.22	22.7	22.8
Potassium (K)	mg	0.863	3.76	275	274
Sodium (Na)	mg	<0.001	1.06	83.0	73.5
Zinc (Zn)	mg	0.035	2.17	3.56	4.25
Iron (Fe)	mg	0.095	1.192	2.97	3.26
VITAMINS					
Thiamine (B1)	mg	<0.001	0.003	0.04	0.02
Riboflavin (B2)	mg	<0.001	0.003	0.04	0.07
Niacin (B3)	mg	0.192	0.114	4.96	5.17
Pyridoxine (B6)	mg	<0.001	0.015	0.20	0.11
Cyanocobalamin (B12))	µg	0.004	0.150	2.37	3.06
LIPIDS: Saturated fatty acids (SFA)					
14:0	g	<0.001	0.007	0.12	0.22
16:0	g	<0.001	0.569	1.22	2.15
18:0	g	<0.001	0.055	0.97	1.91
20:0	g	<0.001	0.001	0.01	0.23
Total saturated fatty acids	g	<0.001	0.125	2.47	4.57
Monounsaturated fatty acids (MUFA)					
16:1	g	<0.001	0.004	0.08	0.14
18:1n9t	g	<0.001	0.006	0.09	0.20
18:1n9c	g	<0.001	0.082	1.93	3.20
Total monounsaturated fatty acid	g	<0.001	0.094	2.18	3.67
Polyunsaturated fatty acids (PUFA)					
18:2n6t	g	<0.001	0.001	0.02	0.04
18:2n6c	g	<0.001	0.005	0.11	0.18
Cholesterol	mg	<0.001	2.160	47.90	61.20
CLA	g	0.185	0.009	0.17	0.26

p-value≤0.05 indicate significant differences

TABLE 7: Mean values of the nutrient composition for raw and cooked 100g fat (subcutaneous + intermuscular) portion of South African C2 mutton

Nutrients analysed	Unit	p-value	SEM	Raw (n=18)	Cooked (n=18)
PROXIMATE ANALYSIS:					
Moisture	g	0.299	1.002	27.39	28.38
Protein (Nx6.25)	g	<0.001	0.626	10.95	11.18
Fat	g	0.014	1.65	64.3	58.1
Ash	g	<0.001	0.0320	0.407	0.628
Energy	kJ	0.033	51.4	2529	2364
LIPIDS:					
Saturated fatty acids (SFA)	g	0.063	1.151	3.57	3.26
Monounsaturated fatty acids (MUFA)	g	0.009	0.616	2.62	2.37
Polyunsaturated fatty acids (PUFA)	g	0.015	0.0994	2.181	1.812
Trans fat	g	0.077	0.0876	1.942	1.713
Cis	g	0.009	0.552	23.42	21.18
Cholesterol	mg	0.236	3.22	65.6	60.0
Omega 3	g	0.002	0.0316	0.595	0.441
Omega 6	g	0.042	0.0729	1.580	1.358

p-value≤0.05 indicate significant differences

TABLE 8: Mean values of the nutrient composition for 100g raw and cooked meat portion (without subcutaneous fat) of Dorper and Merino South African C2 mutton

Nutrients analysed				Dorper (n=9)		Merino (n=9)	
	Unit	p-value	SEM	Raw	Cooked	Raw	Cooked
PROXIMATE ANALYSIS :							
Moisture	g	0.277	0.441	74.0	64.5	73.8	63.4
Protein (Nx6.25)	g	0.752	0.269	20.2	26.1	20.1	26.5
Fat	g	0.745	0.338	4.73	8.34	5.00	8.82
Ash	g	0.030	0.031	1.203	1.05	1.16	1.20
Food energy (calculated)	kJ	0.644	13.930	518	753	530	776
MINERALS:							
Magnesium (Mg)	mg	0.083	0.382	22.1	22.8	23.2	22.7
Potassium (K)	mg	0.521	4.140	276	278	275	270
Sodium (Na)	mg	0.638	3.626	81.9	73.1	84.0	73.8
Zinc (Zn)	mg	0.877	2.650	3.39	4.03	3.73	4.47
Iron (Fe)	mg	0.190	1.437	2.89	3.41	3.05	3.11
VITAMINS:							
Thiamine (B1)	mg	<0.001	0.005	0.03[b]	0.02[a]	0.06[c]	0.02[a]
Riboflavin (B2)	mg	0.340	0.003	0.03	0.06	0.05	0.07
Niacin (B3)	mg	0.266	0.224	4.79	5.20	5.12	5.15
Pyridoxine (B6)	mg	0.599	0.015	0.23	0.12	0.18	0.09
Cyanocobalamin (B12)	µg	0.581	0.265	2.28	2.85	2.46	3.27
LIPIDS: Saturated fatty acids (SFA)							
14:0	g	0.422	0.013	0.12	0.21	0.13	0.23
16:0	g	0.949	0.062	1.19	2.12	1.26	2.18
18:0	g	0.770	0.077	0.93	1.89	1.00	1.92
20:0	g	0.774	0.001	0.01	0.21	0.12	0.03
Total saturated fatty acids	g	0.977	0.137	2.38	4.49	2.56	4.65
Monounsaturated fatty acids (MUFA)							
16:1	g	0.276	0.011	0.078	0.13	0.08	0.14
18:1n9t	g	0.414	0.026	0.07	0.18	0.12	0.23
18:1n9c	g	0.539	0.210	1.94	3.14	1.92	3.26
Total monounsaturated fatty acids	g	0.502	0.235	2.16	3.56	2.20	3.78
Polyunsaturated fatty acids (PUFA)							
18:2n6t	g	0.600	0.002	0.02	0.03	0.02	0.04
18:2n6c	g	0.103	0.013	0.10	0.15	0.13	0.21
Cholesterol	mg	0.079	3.700	45.70	64.70	50.10	57.80
CLA	g	0.043	0.014	0.16	0.22	0.18	0.29

Raw and cooked value from 3 cuts only

p-value≤0.05 indicate significant differences

Nutrient composition of three raw and three cooked cuts per 100g edible portion and 100g meat portion

The edible portion was calculated by adding the nutrient from the fat portion and the meat portion in the quantities as per physical composition (without bone). According to the results (Table 9) for a 100g edible portion of the three raw and cooked cuts on average the moisture decreases during the cooking process. The loin cuts lost a higher percentage of moisture during cooking than the other cuts which may be due to the fact that the loin cut was cooked according to a dry heat cooking method while the other cuts were cooked according to a moist heat cooking method. The subcutaneous fat and intermuscular fat was combined and analysed together in this study, based on the fact that although the amount of fat varies between the different cuts of the animal (Latham, 1997) there is no difference in the fatty acid composition between these tissues (Juarez, Horcada, Alcade, Valera, Mullen & Molina, 2007). The fat content of the loin cut increased with 4.36g during cooking. As fat content increased during cooking, the protein content decreased per 100g portion (Enser *et al.*, 1998).

Of the three raw cuts, the leg had more fat (9.2g) when compared to the shoulder (8.9g) and the loin (8.9g) cuts but had the lowest fat content in edible cooked portion. With the leg containing less than 10g fat per 100g edible cooked portion it qualifies for the heart foundation. In a study done by Hoke, Buege, Ellefson and Maly (1999), it was found that there exists an inverse relationship between moisture and fat content. This fact seems to correlate with the three C2 cuts analysed in this study. The edible portion of the cooked leg cut contains less total fat and less saturated fat than the other cuts and contains 12.9mg less cholesterol than the cooked loin cut.

Although the loin cut contained high quantities of potassium, sodium and iron, the zinc content was low when compared to the other cuts. The cooked shoulder cut contained lower amounts of most minerals (magnesium, potassium, and iron) when compared to the other cooked cuts but had high cyanocobalamin content. The cooked shoulder (58.8g) and leg (57.9g) cut contained less cholesterol than the loin cut (70.8g).

Mutton contains a selection of micronutrients which are required for general heath and well-being with some being present in substantial amounts. In Table 9 the mean values of the nutrient composition for the interaction between raw and cooked cuts expressed per 100g edible portion for South African C2 mutton 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 moisture, protein, fat, sodium, pyridoxine and cholesterol. As expected, moisture losses due to cooking resulted in an increase in the protein and cholesterol concentrations. The same trend was clear in the meat portion of the three cuts (Table10), where moisture losses lead to increase in protein and cholesterol. The fat content of 100g meat portion is less than 10g for all three cuts. As consumers trim their meat on the plate they don't consume subcutaneous fat with the meat often.

TABLE 9: Calculated mean values of the nutrient composition of three raw and three cooked cuts per 100g edible portions (meat and fat) of South African C2 mutton

Nutrients analysed		Raw cuts (n = 3)			Cooked cuts (n = 3)		
	Unit	Shoulder	Loin	Leg	Shoulder	Loin	Leg
PROXIMATE ANALYSIS:							
Moisture	g	73.8	74.0	73.7	66.5	63.2	64.0
Protein (Nx6.25)	g	20.4	20.7	20.2	24.9	26.9	28.7
Fat	g	8.85	8.85	9.24	11.69	13.21	9.91
Ash	g	1.19	1.20	1.18	1.25	1.11	1.12
Food energy (calculated)	kJ	667	682	689	860	951	857
MINERALS:							
Magnesium (Mg)	mg	21.88	23.0	21.9	21.1	23.0	24.2
Potassium (K)	mg	256	282	256	262	280	280
Sodium (Na)	mg	86.9	85.7	86.9	74.8	77.6	68.0
Zinc (Zn)	mg	38.8	3.23	3.88	4.64	3.72	4.41
Iron (Fe)	mg	28.0	2.93	2.80	2.75	3.23	3.81
VITAMINS:							
Thiamine (B1)	mg	0.05	0.04	0.04	0.03	0.03	0.02
Riboflavin (B2)	mg	0.04	0.03	0.04	0.07	0.05	0.08
Niacin (B3)	mg	4.75	5.17	4.95	4.89	5.43	5.20
Pyridoxine (B6)	mg	0.17	0.23	0.21	0.09	0.12	0.11
Cyanocobalamin (B12)	µg	2.68	2.08	2.35	3.43	2.60	3.14
LIPIDS:							
Saturated fatty acids (SFA)							
14:0	g	0.25	0.25	0.26	0.32	0.37	0.27
16:0	g	2.27	2.27	2.33	2.97	3.42	2.49
18:0	g	1.90	1.99	1.94	2.68	3.28	2.07
20:0	g	0.02	0.03	0.02	0.03	0.04	0.03
Monounsaturated fatty acids (MUFA)							
16:1	g	0.15	0.14	0.16	0.19	0.20	0.18
18:1n9t	g	0.19	0.20	0.21	0.27	0.33	0.24
18:1n9c	g	3.39	3.30	3.58	4.41	4.67	3.88
Polyunsaturated fatty acids (PUFA)							
18:2n6t	g	0.04	0.04	0.04	0.05	0.06	0.04
18:2n6c	g	0.19	0.17	0.19	0.23	0.24	0.21
Cholesterol	mg	49.9	51.0	50.0	58.8	70.8	57.9

TABLE 10: Mean values of the nutrient composition of three raw and three cooked cuts per 100g meat portions of South African C2 mutton

Nutrients analysed		Raw cuts (n = 3)			Cooked cuts (n = 3)		
	Unit	Shoulder	Loin	Leg	Shoulder	Loin	Leg
PROXIMATE ANALYSIS:							
Moisture	g	73.3	73.7	74.7	65.8	62.7	63.4
Protein (Nx6.25)	g	19.9	20.4	20.5	24.4	26.3	28.1
Fat	g	5.79	4.96	3.84	8.74	9.80	7.20
Ash	g	1.16	1.18	1.21	1.22	1.09	1.07
Food energy (calculated)	kJ	551	530	490	738	810	744
MINERALS:							
Magnesium (Mg)	mg	21.9	22.9	23.2	21.1	23.0	24.2
Potassium (K)	mg	256	282	288	262	280	280
Sodium (Na)	mg	86.9	85.7	76.3	74.8	77.6	68.0
Zinc (Zn)	mg	3.88	3.23	3.57	4.64	3.72	4.41
Iron (Fe)	mg	2.80	2.93	3.17	2.75	3.23	3.81
VITAMINS:							
Thiamine (B1)	mg	0.050	0.035	0.042	0.027	0.025	0.017
Riboflavin (B2)	mg	0.042	0.030	0.040	0.067	0.053	0.075
Niacin (B3)	mg	4.75	5.17	4.95	4.89	5.43	5.20
Pyridoxine (B6)	mg	0.17	0.228	0.210	0.087	0.122	0.110
Cyanocobalamin (B12)	µg	2.68	2.08	2.35	3.43	2.60	3.14
LIPIDS:							
Saturated fatty acids (SFA)							
14:0	g	0.152	0.120	0.091	0.218	0.256	0.183
16:0	g	1.45	1.27	0.950	2.17	2.50	1.78
18:0	g	1.15	1.01	0.733	1.90	2.35	1.48
20:0	g	0.014	0.011	0.008	0.022	0.029	0.018
Monounsaturated fatty acids (MUFA)							
16:1	g	0.095	0.078	0.068	0.140	0.141	0.124
18:1n9t	g	0.113	0.094	0.070	0.203	0.235	0.172
18:1n9c	g	2.29	1.94	1.56	3.34	3.46	2.80
Polyunsaturated fatty acids (PUFA)							
18:2n6t	g	0.022	0.018	0.014	0.036	0.042	0.030
18:2n6c	g	0.132	0.114	0.091	0.181	0.188	0.162
Cholesterol	mg	47.8	49.5	46.3	57.3	69.8	56.5
CLA	g	0.197	0.159	0.162	0.262	0.275	0.236

Comparison between current study and MRC food composition tables

Results demonstrate that meat cuts vary in its contribution to the diet. When comparing the new food composition data for mutton (C2) from the study with the current data included in the South African food composition tables (Sayed *et al*., 1999) there are differences in the nutrient composition of these two sets of data (Table 11), as previous data was obtained from USDA Food Composition Tables. This is in agreement with Greenfield and Southgate (2003) who stated that nutritional composition data varies between different countries. According to Vandendriessche (2008) the main attributes of meat contributing to the negative health image are the fat level, the sodium level and the fat quality in terms of fatty acid composition with the fat content of meat remaining the biggest problem (Vandendriessche, 2008), but with data showing that raw mutton contains 12.6g less fat per 100g edible portion, it may overcome this problem. Although the CLA content in the current study indicates

that mutton is lower in CLA, any amount of CLA present in meat is seen as value added (Corino, Filetti, Gambacorta, Manchisi, Magni, Pastrolli, Rossi & Maiorano, 2003).

The vitamin and mineral content of the raw and cooked mutton (C2) from the current study is lower except for potassium, iron and vitamin B_{12}. Cooked South African mutton (data from current study) contains 1.26g more iron per 100g edible portion than that published in MRC tables (Table 10). The moisture content between the raw values of the current study and MRC tables differ with 13.1g and it only differs with 7.06g in the cooked sample. A similar tendency was apparent in the sodium content as the sodium difference between the current study and MRC table was higher (28.5g) than the sodium difference between the current study and MRC tables for the cooked portion (7.43g). This indicates that there was possibly a difference in the cooking method (end temp, internal temp or time of cooking) between the two studies.

TABLE 11: Comparison of the nutrient composition for raw and cooked 100g edible portion of lean mutton between the South African 1999 MRC food composition tables and the results of the current study on the C2 mutton

		Raw		difference between studies[3]	Cooked		difference between studies[3]
Nutrients analysed	**Unit**	**Current study[1]**	**1999 MRC tables[2]**		**Current study[1]**	**1999 MRC tables[2]**	
PROXIMATE ANALYSIS:							
Moisture	g	73.8	60.7	13.1	64.6	57.5	7.06
Protein (Nx6.25)	g	20.5	16.9	3.6	26.8	25.6	1.23
Fat	g	8.98	21.6	-12.62	11.6	16.5	-4.9
Ash	g	1.19	0.9	0.29	1.16	1.0	-.16
Food energy (calculated)	kJ	679	1087	-408	889	1046	157
MINERALS:							
Magnesium (Mg)	mg	22	22	0	23	24	-1
Potassium (K)	mg	264	230	34	274	313	-39
Sodium (Na)	mg	86.5	58	28.48	73.4	66	7.43
Zinc (Zn)	mg	3.66	3.33	0.33	4.26	4.4	-0.14
Iron (Fe)	mg	2.84	1.6	1.24	3.26	2	1.26
VITAMINS:							
Thiamine (B1)	mg	0.04	0.12	-0.08	0.02	0.1	-0.08
Riboflavin (B2)	mg	0.04	0.22	-0.18	0.07	0.27	-0.2
Niacin (B3)	mg	4.96	6.1	-1.14	5.17	6.6	-1.43
Pyridoxine (B6)	mg	0.2	0.13	0.07	0.11	0.15	-0.04
Cyanocobalamin(B12))	µg	2.37	2.4	-0.03	3.06	2.6	0.46
LIPIDS:							
Saturated fatty acids (SFA)	g	4.71	9.47	-4.76	6.07	6.89	-0.82
14:0	g	0.25	0.87	-0.62	0.32	0.64	-0.32
16:0	g	2.42	4.75	-2.33	2.96	3.51	-0.55
18:0	g	1.94	2.98	-1.04	2.67	2.22	0.45
20:0	g	0.10	0	0.1	0.03	0	0.03
Monounsaturated fatty acids(MUFA)	g	3.77	8.86	-5.09	4.79	6.96	-2.17
16:1	g	0.15	0.63	-0.48	0.19	0.48	-0.29
18:1	g	3.62	7.96	-4.34	4.60	6.32	-1.72
Polyunsaturated fatty acids (PUFA)	g	0.19	1.7	-1.51	0.28	1.18	-0.9
18:2	g	0.19	1.24	-1.05	0.28	0.9	-0.62
Cholesterol	mg	50.32	72	-21.68	62.51	93	-30.49

[1] Data calculated from current study (Table 9)
[2] Sayed *et al.*, 1999
[3] Difference: Calculated on the difference between the values of the current study (Table 9) and that of the 1999 MRC food composition tables (Sayed *et al.*, 1999)
\- Indicates that the current study has less of the particular nutrient than the MRC-tables

Recommended Dietary Allowances

To evaluate the nutrient contribution of mutton (C2) from this study, the RDA for males, aged 25 - 50 years (Whitney & Rolfes, 2002), was used as the reference point. A 100g portion of cooked leg, loin and shoulder mutton cuts provides on average 42.6% protein, 34.3% potassium and 127.4% vitamin B_{12} of RDA for this group of males (Table 12). A 100g portion further provides 32.3% vitamin B_3, 32.6% iron, 28.4% zinc, 5.0% vitamin B_2, 6.3% vitamin B_6 and 1.9% vitamin B1 of the RDA.

TABLE 12: Contribution of 100g edible portions of cooked (deboned) meat from three C2 mutton 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	-	66.47	-	63.18	-	64.04	-	-
Protein (Nx6.25)	g	63	24.89	39.5	26.86	42.63	28.74	45.62	42.58
Fat	g	-	11.69	-	13.21	-	9.91	-	-
Ash	g	-	1.25	-	1.11	-	1.12	-	-
Food energy (calculated)	kJ	12 180	860	7.06	950	7.80	857	7.04	7.3
MINERALS:									
Magnesium (Mg)	mg	420	21.10	5.02	22.99	5.47	24.20	5.76	5.42
Potassium (K)	mg	800	261.88	32.74	280.40	35.05	280.40	35.05	34.28
Sodium (Na)	mg	-	74.80	-	77.56	-	67.98	-	-
Zinc (Zn)	mg	15	4.64	30.93	3.72	24.8	4.41	29.4	28.38
Iron (Fe)	mg	10	2.75	27.5	3.23	32.3	3.81	38.1	32.63
VITAMINS:									
Thiamine (B1)	mg	1.2	0.03	2.25	0.03	2.08	0.02	1.42	1.92
Riboflavin (B2)	mg	1.3	0.07	5.15	0.05	4.08	0.08	5.77	5.00
Niacin (B3)	mg	16	4.89	30.58	5.43	33.93	5.20	32.51	32.34
Pyridoxine (B6)	mg	1.7	0.09	5.12	0.12	7.18	0.11	6.47	6.25
Cyanocobalamin(B12)	µg	2.4	3.43	142.92	2.60	108.33	3.14	130.83	127.36

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

Nutrient density and the Index of Nutritional Quality

According to Wardlaw and Insel (1996) RDA's are very useful for planning and evaluating complete diets but aren't useful for assessing the nutritional quality of an individual food. Nutrient density is used for this purpose as it measures 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:

Nutrient density is calculated as follows:

$$\frac{\text{Amount of micronutrient present in food}}{\text{kJ content of food}} \times \frac{\text{kJ RDA}}{\text{RDA of micronutrient}}.$$

To calculate the nutrient density of iron in 100g cooked deboned edible portion of shoulder (iron 2.75mg, energy: 860 kJ) in the diet of males 25-50 years (RDA for iron: 10mg and energy: 12 180 kJ):

$$\frac{2.75\text{mg}}{860\text{ kJ}} \times \frac{12180\text{ kJ}}{10\text{mg}} = 3.89$$

A value exceeding 1 indicates the positive contribution of a nutrient. Three of the cooked mutton cuts, supply significant quantities of a range of protein, iron, zinc and vitamin B_{12} for a limited amount of energy (Table 13). The more nutrients present and the fewer kiloJoules, the higher the nutrient density.

TABLE 13: Indices of the diet quality for cooked, deboned South African C2 mutton cuts

NUTRIENTS	100g EDIBLE PORTION		
	Nutrient density[1]		
	Leg	Loin	Shoulder
Protein	6.47	5.45	5.58
Iron	5.41	4.26	3.89
Zinc	4.18	3.17	6.38
Vitamin B_{12}	18.59	13.89	20.24

Nutrient Density = ≥ 1.00: good source.
[1] Calculated using data from table 9 and Whitney and Rolfes (2002)

CONCLUSION

It is evident from this study that South African mutton (C2) provides a variety of valuable nutrients. Results indicate that nutrients vary between the raw and the cooked cut. The main cause for this change is the loss of moisture which consequently leads to higher concentrations of the nutrients. Cooking affects mainly the protein, potassium, zinc and energy values, which were higher in the cooked meat cuts, but in addition differed between the different cooked cuts. Soluble micronutrients can also be lost during the cooking process. Although micronutrients are lost during the cooking process through leaching and solubility, South African mutton (C2) can be regarded as an important dietary source of the B vitamins, iron, and zinc. There was no significant difference in the iron values between the cooked cuts.

Differences were apparent upon comparing the nutrient composition of a 100g edible portion of the different raw and cooked cuts. During the cooking process moisture decreased in all three cuts while most heat stable nutrients increased. Vitamin B_{12}, B_3, B_2 and zinc increased in all three cuts during cooking while sodium, vitamin B_1 and vitamin B_6 decreased in all three cuts. It is recommended that the effect of cooking temperature on vitamins be considered in future studies.

Upon comparing the current result with the MRC food composition tables of 1999, it is clear that there are significant differences. The current study indicates that cooked South African mutton (C2) contains 4.9g less fat and 30.5mg less cholesterol per cooked edible portion than previously published in MRC tables. These new results show that the leg cut of mutton (C2) classifies for the Heart Foundation mark of approval as it contains less that 10g fat per 100g edible portion. These results

indicate that South African mutton (C2) is an excellent source of protein, iron, zinc and vitamin B_3 as it makes a valuable contribution to the RDA of these nutrients for males, aged 25 – 50 years when included as part of a balanced meal plan. Therefore, it can be recommended that lean mutton meat can be consumed in moderation and form part of a healthy balanced diet.

It is also of importance to note that when meat is cooked with all associated fat and is then trimmed from cut prior to eating, it contains on average 8,58g fat per 100g meat. This is a meaningful recommendation to consider when advising consumers on lean meat. Accurate local data on nutrient composition is essential for assessing dietary intakes 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 mutton (C2). Therefore this study contributes valuable data by providing an accurate nutrient profile of South African mutton of age class C and fat class 2.

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5

A DISCUSSION OF MICRONUTRIENT INTERACTIONS BETWEEN RED MEAT AND GREEN LEAFY VEGETABLES

ABSTRACT

An estimated 66% of children in South Africa suffer from vitamin A deficiency (Labadarios, Moodie & Van Rensburg, 2008), 45% from zinc deficiency (Dhansay, Marais & Labadarios, 2008) and 33% from iron deficiency anaemia with the prime factors contributing towards this being inadequate dietary intake and poor availability of micronutrients from food (Labadarios & Louw, 2008). Maize and bread are commonly consumed foods in South Africa and the consumption of red meat and vegetables remains low (Van Vuuren, 2006). Traditionally, as part of their cultural heritage, people in South Africa practised mixed farming, which involved the production of both crops and animals on different types of land.

Food-based approaches targeting the relief of iron deficiency usually encourage the consumption of animal foods together with the consumption of green leafy vegetables (GLV), due to the high bioavailability of heme iron in animal foods (Ruel, 2001). Non heme iron (found in GLV) absorption is influenced by soluble enhancers and inhibitors consumed during the same meal. Unknown factors present in meat (called the meat factor) are known to enhance the nonheme iron absorption. The inclusion of GLV and red meat, two micronutrient rich foods, can be a strategy based on mutual supplementation to combat nutritional deficiencies as it has the potential to alleviate numerous micronutrient deficiencies including iron and vitamin A deficiency. It holds the possibility to enhance the absorption of specific micronutrients and thus may pose higher benefits in alleviating malnutrition. The mutual supplementation strategy is based on the fact that red meat is an expensive food choice and therefore largely unaffordable for most resource poor consumers most likely to suffer from micronutrient deficiencies and that GLV is readily available and can be gathered as a food coping strategy. In this discussion it is proposed that a small amount of red meat added to GLV may enhance absorption of limiting micronutrients.

Key words: Green leafy vegetables, mutton, micronutrient nutrient interaction, iron, vitamin A

INTRODUCTION

South Africa exports food, yet a large section of its population experiences food insecurity and malnutrition in the form of micronutrient deficiencies (Van Vuuren, 2006). Maize and bread remain the most commonly consumed foods in South Africa and the consumption of red meat and vegetables remains low (Van Vuuren, 2006). Starch based diets are known to be high in rice, maize and millet and contain limited amounts of fruits and vegetables. These diets are associated with micronutrient deficiencies due to the poor availability of the essential micronutrients iron and zinc (Agte, Tarwadi, Mengale & Chiplonkar, 2000). An estimated 66% of children in South Africa (SA) suffer from vitamin A deficiency and 33% from iron deficiency anaemia. Zinc deficiency among children is also increasing and currently 45% of all children in SA are zinc deficient (Dhansay *et al*., 2008). The prime factors for these micronutrient deficiencies are inadequate dietary intake and poor availability of micronutrients from food (Kumari, Gupta, Lakshmi & Prakash, 2004). However, black people in South Africa traditionally practised mixed farming, which involved the production of both crops and animals on different types of land (Mkile, 2001). Due to high cost involved in interventions to combat micronutrient deficiencies, such as food fortification or supplementation, a food based intervention may be more beneficial on the longer term. Inclusion of green leafy vegetables (GLV) and red meat, two micronutrient rich foods, can be an alternative strategy to combat nutritional deficiencies (Agte *et al*., 2000). Inclusion of GLV and red meat in the diet has the potential to alleviate micronutrient deficiencies such as iron and vitamin A deficiency. Consumption of other micronutrient rich foods in conjunction with GLV holds the possibility of enhancing the absorption of specific micronutrients and thus may pose higher benefits in alleviating malnutrition.

MOTIVATION

Funding was obtained from the NRF, but the funding was not sufficient for experimental research. Therefore it was decided to do a literature review looking towards benefits of combining GLV and red meat.

OBJECTIVE

The objective of this review is to explore the current knowledge on micronutrient interaction between GLV and red meat. This knowledge will be used as a guide when discussing micronutrient deficiency strategies.

GREEN LEAFY VEGETABLES

Plants form a major part of most diets around the world and are the major source of energy in most developing countries (Southgate, 1998). Surveys indicate that there are over 7 000 plant species

across the world, cultivated or harvested from the wild for food. These neglected and underutilized species often play an important role in food security, income generation and food culture of the rural poor, and could play an even bigger role. The potential of these plants is however, mostly under-estimated and under-exploited. There exist more than one thousand edible plants of which most parts of the plants can be consumed (Southgate, 1998; Van Wyk, 2003). Numerous of these neglected and underutilized species have a high nutrient content and could contribute to food insecurity. By motivating communities to increase their consumption of these indigenous and traditional dark green leafy vegetables, food insecurity could be reduced (IPGRI, 2000-2005). Some communities in South Africa already supplement their diet with indigenous crop species such as misbredie (*Amaranthus cruentus),* pumpkin leaves *(Curcubita maxima)* cat's whiskers *(Cleome gynandra),* cowpea leaves (*Vigna unguiculata),* wild jute (*Corchorus olitorius) and* spider plant (*Cleome gynandra*) (Van Vuuren, 2006; Steenkamp & Schönfeldt, 2005). The tender leaves, young shoots and even flowers of the spider plant are eaten boiled as a tasty relish or side dish. The leaves are very nutritious and freshly eaten with other mashed foods or dried and ground and added to weaning foods (Van Vuuren, 2006). Amaranthus is a very nutritious common weed in South Africa which can be harvested from wild-growing or cultivated plants. Of the various types, the green types are less bitter than the red ones. These plants grow easily under various weather and soil conditions (Van Vuuren, 2006). In South Africa these leafy vegetables and combinations of leafy vegetables are known as morogo or imifino (Van Vuuren, 2006). GLV mainly come from short-lived herbaceous plants although the leaves of woody plants can also be eaten. The leaves, stems, modified buds and flowers of young leafy vegetables are all consumed. According to Southgate (1998) leafy vegetables belong to one of the three families; *Cruciferae, Compositeae and Umbelliferous*. The family *Cruciferae* includes the *Brassica* vegetables such as cabbage, brussel sprouts, kale, cauliflower, sprouting broccoli, kohlrabi as well as watercress, spring greens and the young leaves of turnips. Lettuce and chicory are popular plants eaten from the *Compositeae* family, and from the *Umbelliferous* family, plants such as parsley, dill, chervil and samphire are grown for their leaves, celery, angelica and fennel for their stems and spinach and a range of beets for their leaves (Southgate, 1998). GLV contains antioxidants such as flavonoids, isoflavins, lignans, catechins and isocatechins that are antidiabetic, antihistaminic, anticarcinogenic and antibacterial (Subhasree, Baskar, Keerthana, Susan & Rajasekaran, 2009).

The production of plant foods is usually seasonal and prone to microbial spoilage once harvested due to the high moisture content (Southgate, 1998). According to Els (2007) it is best to harvest the individual leaves in order to let the plant regenerate more leaves. In GLV varieties with heads rather than loose leaves, the head are left until it matures, upon which the whole head is harvested.

Nutritional importance of green leafy vegetables

Cultural and traditional reasons as well as affordability are some of the main factors influencing consumption patterns (Jamora & Rhee, 1998; Latham, 1997). GLV in South Africa have long been recognised as the most affordable and nutrient dense food containing protein, iron, calcium, vitamin C,

ß-Carotene and folic acid (Agte *et al*., 2000; Aletor, Oshodi & Ipinmoroti, 2001). Although the nutrient levels are relatively low on a weight basis, the leaves are usually consumed in large portions and thus can make a significant nutritional contribution to the diet (Southgate, 1998). GLV are low in energy and fat content and high in protein content and contain high amounts of fiber. The fiber found in GLV may have a negative influence on the absorption of carotenoids from the GLV as carotenoids can be trapped in the fibrous region of the chloroplast (Williams & Erdman, 1996). According to Els (2007) GLV contain more vitamins and minerals and fewer kiloJoules than any other vegetable and/or other food type probably. In a study performed at the University of Pretoria (Steenkamp & Schönfeldt, 2005) the nutrient analysis of the traditional South African dark green leafy vegetables revealed that it is a good source of protein, minerals (iron, calcium, phosphorus and magnesium) and β-carotene. It is hypothesized that vitamin A deficiency would be less prevalent if vitamin A rich foods were consumed under more favourable conditions (Williams & Erdman, 1996). According to West, Eilander and Van Lieshout (2002) the vitamin A from plant foods is much less bioavailable than previously thought. Raw GLV's are at the bottom of the hierarchy of carotenoid bioavailability (Figure 1). Food matrix, processing conditions, nutrient interactions and fat content of the meal may increase the bioavailability of the carotenoids found in GLV (Williams & Erdman, 1996).

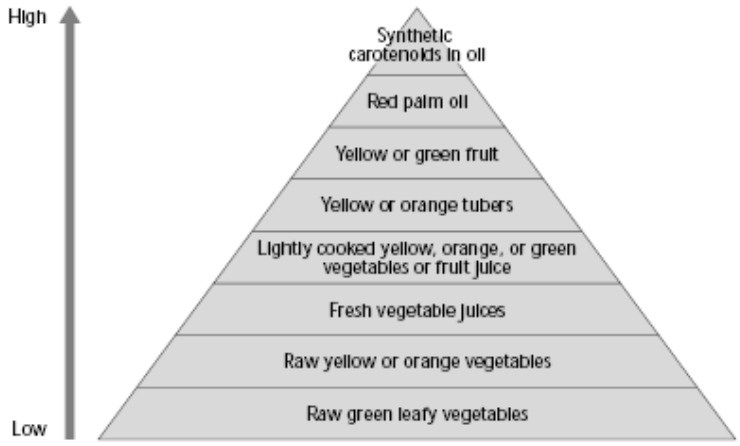

FIGURE 1: Hierarchy of carotenoid bioavailability foods (Underwood, 2000)

According to Aletor *et al*. (2001) the amino acid profile of GLV proteins from most species compares well with those of soybean, meat, fish and egg, the exception being that leaf proteins contain lower amounts of methionine. Studies have shown that these leaves are usually consumed cooked and although GLV include a wide variety of plants, they have very similar nutritional contents and similar cooking methods are applied (Els, 2007). Using moist heat cooking methods when preparing GLV will prevent amino acid deterioration as amino acids are more sensitive to dry heat (Williams & Erdman, 1996). Africa has the highest percentage of resource-poor persons that have great needs for such an essential source of high quality protein containing amino acids (Aletor *et al*., 2001). In Table 1, the

nutrient content of the GLV found in South Africa (Agte *et al.*, 2000) is presented. The major importance of GLV lies in its contribution to vitamin intake as they contain significant amounts of beta-carotene, riboflavin, thiamine, folic acid and ascorbic acid (Southgate, 1998), as well as smaller amounts of the minerals iron, copper and zinc (Table 2).

TABLE 1: Nutrient content of 100g green leafy vegetables consumed in South Africa (Steenkamp & Schönfeldt, 2005)

Name		Fat (g)	Protein (g)	Beta-carotene (µg)	Vit C (mg)	Riboflavin (µg)
RDA* Males (25-50		-	63	6000	80	1.3
Misbredie *(Amaranthys cruetus)*	Raw	0.2	3.5	1710	5.38	0.03
	Cooked	0.1	3.5	1200	4.00	0.01
Pumpkin leaves *(Curcubita maxima)*	Raw	0.2	4.2	1309	5.67	0.12
	Cooked	0.1	3.7	593	2.41	0.08
Cat Whisker's *(Cleome gynandra)*	Raw	0.4	5.7	5517	6.45	0.08
	Cooked	0.2	4.5	2329	5.54	0.06
Cowpea leaves *(Vigna unguiculata)*	Raw	0.1	4.1	2328	4.72	0.05
	Cooked	0.1	3.0	1290	1.38	0.04
Wild Jute (Corchorus olitorius)	Raw	0.3	5.2	-	5.51	0.07
	Cooked	0.1	3.8	-	3.77	0.04

Trace minerals such as zinc and copper present in GLV are mostly absorbed from the soil. The zinc, copper and iron found in GLV are illustrated in Table 2.

TABLE 2: Mineral content of 100g green leafy vegetables consumed in South Africa (Steenkamp & Schönfedt, 2005)

Name		Fe (mg)	Zn (mg)	Mg (mg)	Ca (mg)	P (mg)
RDA* Males (25-50)		10	15	420	800	800
Misbredis *(Amaranthys cruetus)*	Raw	16.2	0.8	141.2	232.3	70.6
	Cooked	8.4	0.7	104.9	272.2	64.9
Pumpkin leaves *(Curcubita maxima)*	Raw	15.9	0.9	142.3	383	119.2
	Cooked	15.6	0.7	111.3	350.4	101.8
Cat Whisker's *(Cleome gynandra)*	Raw	14.3	1.0	146.4	392.6	146.7
	Cooked	14.5	1.0	61.4	265.1	109.6
Cowpea leaves *(Vigna unguiculata)*	Raw	3.9	0.5	54.7	221.2	80.1
	Cooked	3.0	0.4	34.5	150.6	56.7
Wild Jute (Corchorus olitorius)	Raw	6.8	1.2	74.2	586.3	138.2
	Cooked	6.3	0.8	8039	584.6	136.3

* Whitney and Rolfes (2002), RDA for males 25-50 years.

The nutrient content of GLV differs between raw and cooked states. During the cooking process the proteins present in the GLV are denatured while the carbohydrates are broken down to simple sugars (Southgate, 1998). Cooking of the GLV is beneficial as it aids in making the product more digestible.

According to Southgate, (1998) using small amounts of water when cooking GLV can reduce vitamin losses. However, cooking can reduce the ascorbic acid content up to 64% (Kumari *et al*., 2004), especially when the vegetables are left standing when cooked prior to consumption (Southgate, 1998). Freezing however, has minor effects on the loss of the labile vitamins, canning produces greater losses and drying may result in a complete loss of ascorbic acid and folate (Southgate, 1998).

RED MEAT

Meat is a nutrient dense food but mostly too expensive to be purchased by lower income groups. Consumers purchase more animal products as their income increases. Meat contributes various essential nutrients to the body that are needed for normal and optimal growth, as well as functioning of the immune system and general metabolism of substrates (Badiani, Nanni, Gatta, Bitossi, Tolomelli & Manfredini, 1998; Enser, 2000). Meat is an excellent source of protein, essential fatty acids, oleic and linoleic acid as well as minerals such as iron, zinc and phosphorous and the B-vitamins (Badiani *et al*., 1998). Folate and iron in a red meat matrix are more bioavailable than when obtained from a plant source (Biesalski, 2005). Red meat is associated with a fat intake (Biesalski, 2005) which may have beneficial effects on the absorption of fat soluble vitamins in the diet. Despite the associated benefits of red meat, it is not regularly consumed in poor communities due to financial implication. Different studies such as the CORIS study, the BRISK study from Cape Peninsula and the THUSA study have been conducted in order to study the red meat intake of different populations (Scholtz, H.H. Vorster (junior), Matshego & H.H. Vorster, 2001). According to Kruger, Schönfeldt and Owen (2008) poor communities in rural South Africa have on average R1,60 per person per day. Therefore these households cannot afford to purchase protein-rich foods for every meal or even regularly. Cheap alternatives such as chicken feet and soy mince are used to make a diluted soup to consume the starchy staple food.

Nutritional importance of red meat

Animal products are a source of high quality protein with the three most abundant muscle protein found in red meat being myosin, actin and triptomyosin (McWilliams, 2005). The high biological value of protein in meat is a good complement to the limiting amino acids in plant foods as red meat contains on average 19 percent protein of high amino acid quality (Latham, 1997). Red meat also includes all the essential amino acids which are important for human growth and development as well as contributing zinc, bioavailable iron and vitamin B_{12} (Enser, 2000).

Red meat is an essential source of vitamins and minerals, either because it is the only source of the specific micronutrient, or because meat has a higher bioavailability for some micronutrients (Biesalski, 2005). Vitamin E, a fat soluble vitamin present in red meat, is generally accepted as an antioxidant and plays an integral role in the prevention of chronic diseases by donating hydrogens from their

phenolic group to stabilize radicals and stop the oxidative chain reaction (Elmafda, Anklam & Konigs, 2003). The bioavailability of folate and iron found in red meat is high and thus more readily absorbed than these minerals from plant sources. Ruminant fat naturally contains the fatty acid Conjugated Linoleic Acid (CLA) with beneficial pharmacological activity. These beneficial effects associated with CLA counteract the effects of the trans unsaturated fatty acids found in ruminant fat (Enser, 2000).

NUTRIENT INTERACTIONS

Deficiency of trace minerals in humans may be a result of inadequate consumption of minerals in the diet or poor bioavailability of nutrients or adequate dietary intake (Sandström, 2001). Factors that may affect the bioavailability of nutrients from foods include the chemical form of the nutrient (Table 3), the amount of dietary fat in the meal, the nutritional status of the individual and the presence of inhibitors or promotors (Williams & Erdman, 1996). Heme iron found in red meat is highly available (25%) compared to nonheme iron from GLV (3-8%). When consuming foods with different micronutrient contents, interaction between the micronutrients may occur. Factors that decrease or impair absorption include dietary constituents, such as fiber, drugs or other chemicals that may interact with essential trace minerals and interactions between essential nutrients. According to Yip (2001), chemically similar elements may share a pathway for absorption, thus resulting in competition for uptake into the mucosal cells. There are a number of inter relations that can be present and should be considered especially when fortifying foods, or developing supplements (Sandström, 2001).

A potential risk of interactions between micronutrients affecting absorption and bioavailability has to be considered in any micronutrient alleviation strategy (Yip, 2001). At levels of essential micronutrients present in foods, most micronutrients appear to utilise specific absorptive mechanisms and not be vulnerable to interactions. Minerals with chemical similarities can compete for transport of proteins or other uptake mechanisms, as well as for chelating organic substances, facilitating or hindering absorption. The quantitative consequences of these interactions will depend on the relative concentrations of the nutrients (Sandström, 2001). A poor nutritional status with regard to vitamins affects mucosal integrity and can thereby affect absorption of other nutrients. In a similar way trace element deficiencies could affect general absorptive capacity, as well as specific mechanisms needed for uptake of other micronutrients.

Table 3: Comparison of mineral content and bioavailability of a 100g portion of raw green leafy vegetable and raw edible mutton portion

Nutrient	GLV/100g[1]	Bioavailability factor [2]	Amount Absorbed/100g	Mutton/100g[3]	Bioavailability factor[2]	Amount Absorbed/100g
Zinc	0.60 mg	16.0%	0.10 mg	3.66 mg	-	-
Nonheme Iron	0.71 mg	3-8%	0.02 - 0.06 mg	1.70 mg	3-8%	0.05 – 0.14 mg
Heme Iron	0 mg	-	-	1.14 mg	25%	0.29 mg

Total Iron	0.71 mg	-	0.02 - 0.06 mg	2.84 mg	-	0.34 – 0.43 mg

1 Agte *et al.* (2000)
2 Du, Zhai, Wang and Popkin (2000)
3 Current study (2008)
- Not determined/available

Micronutrient interactions

Considering the high number of South Africans with nutritional deficiencies such as iron, vitamin A and iodine it poses a great need for nutrition knowledge regarding micronutrient interaction. Awareness of these interactions between micronutrients, combined with a balanced evaluation of the dietary intake of the population and the risk of multiple deficiencies, could lead to more effective strategies to improve the nutritional status (Sandström, 2001).

Iron

Approximately 2 billion persons worldwide suffer from iron deficiency. According to Labadarios and Louw (2008) 33% of the women and children in South Africa have moderate or severe iron deficiency anaemia. Iron deficiency is mainly due to nutritional deficiency in developing countries and is also the major micronutrient deficiency in developed countries (Yip, 2001). Iron deficiency whether resulting from inadequate intake or decreased absorption is the primary source of nutritional anaemia (Whittaker, 1998). Iron deficiency is often accompanied by other nutrient deficiencies such as zinc and copper deficiencies, especially when the iron deficiency is caused by insufficient dietary intakes of micronutrients, as is often the case in developing countries (Troost, Brummer, Dainty, Hoogewerff, Bull & Saris, 2003). In order to combat these deficiencies, numerous strategies such as supplements containing iron and other trace minerals rather than food sources are employed (Sandström, 2001). Of the twelve iron sources listed as GRAS (Generally Recognised as Safe), elemental iron has become the source of choice because it is less expensive to produce and has fewer organoleptic problems. According to Whittaker (1998) the usage of ferrous fumurate is also increasing.

Iron absorption is influenced by the dietary iron content, the bioavailability of dietary iron, the amount of storage iron as well as inhibitors and enhancers (Yip, 2001). Absorption of nonheme iron is influenced by the solubility in the upper part of the small intestine. The content of the whole meal greatly influences the solubility of the iron. Thus inhibitors and enhancers greatly influence the absorption of nonheme iron. Factors that may inhibit the absorption of the nonheme iron, include bran, phytic acid present in unprocessed whole grain products, oxalates, tannins and polyphenols present in tea and vegetables as well as calcium supplementation (Kumari *et al.*, 2003; Yip, 2001). Calcium has the same absorption inhibiting effect on heme and nonheme iron in the human body. As heme and nonheme iron are absorbed by different receptors on the mucosal surface, inhibition of calcium must take place within the mucosal cell at a transfer step common to heme and nonheme iron (Sandström, 2001). These interactions only take place when supplemental calcium is added to the meal and not when the meal naturally contains more calcium. Present iron stores influence the effect that calcium has on iron absorption (Hallberg, 1998). Several animal studies have shown that calcium interferes with iron absorption and that the addition of calcium negatively affects serum ferritin and

haemoglobin levels (Hallberg, 1998). Although studies indicate that calcium inhibits the absorption of iron, this has not yet been confirmed in long-term supplementation studies. Unknown factors present in coffee may mildly inhibit the absorption of nonheme iron. Iron absorption can also be inhibited by minerals such as manganese. Manganese affects iron absorption in such a way that the intestine cannot differentiate between manganese and iron. A high manganese intake, as could be the case in tea drinking populations, may therefore impose a risk of reduced iron utilisation (Sandström, 2001).

Ascorbic acid has a strong iron absorption promoting potential and in iron deficient populations ascorbic acid intakes improve iron status and can counteract the inhibitory effects of dietary phytate and tannins on iron absorption (Yip, 2001). Locally available, ascorbic acid rich foods are the first choice alternative to supplementation for enhancing absorption of dietary iron (Sandström, 2001; Yip, 2001). According to Table 1, spinach, a popular GLV in South Africa, contains 22,2mg ascorbic acid in every 100g cooked spinach consumed. Table 2 further indicates that spinach contains 0,8mg iron. According to Sandström (2001) and Yip (2001) the ascorbic acid content in spinach will enhance the absorption of iron. The absorption of iron of GLV can be increased by consuming red meat such as mutton with the GLV. According to Sandström (2001) red meat contains an unknown meat factor that enhances the absorption of nonheme iron from foods such as GLV. Red meat further contains heme iron which is easily absorbed and also enhances the absorption of nonheme iron. Recent studies indicate that vitamin A and B-carotene can also enhance nonheme iron absorption, and thereby contribute to an increase in haemoglobin levels (Sandström, 2001). GLV contain high amounts of vitamin A that can enhance the iron absorption of the nonheme iron in the GLV. Iron deficiency increases the efficiency of iron absorption, and may also affect the absorption of chemically related elements such as manganese and possibly also toxic elements (Sandström, 2001). Animal studies further indicate that riboflavin deficiency affects iron absorption by reducing the absorptive capacity of the gastrointestinal villi (Sandström, 2001). GLV also contain 10–14µg riboflavin per 100g product and can thus aid in preventing riboflavin deficiency which in turn aids iron absorption. Table 4 summarises the factors enhancing and inhibiting iron (heme and nonheme) absorption.

Table 4: Enhancers and inhibitors of nonheme and heme absorption

	Enhancers	Inhibitors
Nonheme iron (GLV)	Ascorbic acid Vitamin A Unknown meat factors Heme iron	Bran, Phytic acid, oxalates, tannins, polyphenols, Calcium supplements, Manganese supplements, unknown factors in coffee
Heme iron (Red meat)	Ascorbic acid	Calcium and Manganese supplements, tannins

Iron and Copper

Copper is essential for iron transport between tissues and one of the signs of copper deficiency is microcytic hypochromic anaemia (Sandström, 2001). Human and animal studies show that an increased iron intake is associated with decreased serum copper concentrations and decreased activity of corresponding copper enzymes. These animal studies provide indications of competitive absorptive mechanisms between iron and copper. The exact mechanism of copper absorption and transport in the human body remains elusive, but studies indicate that copper uptake in the body is not merely mediated by a Divalent metal transporter (DMT1), but also by a transporter hCTR1. Thus copper absorption can continue during excessive iron consumption through absorption by the hCTR1 transporter (Troost *et al*., 2003).

Zinc

Zinc is present in all body fluids and tissue and forms an essential part of more than 300 enzymes participating in the metabolism (FAO/WHO, s.a.). Zinc absorption occurs in the small intestine and is concentration dependent. Although zinc in the body can be circulated, the body doesn't have any zinc stores (FAO/WHO, s.a.). Zinc deficiency is associated with poor growth and development, impaired immune response, loss of appetite, skin lesions, impaired taste acuity, delayed wound healing, hypogonadism and delayed sexual maturation. Zinc status is regulated by strong homeostatic control of absorption and excretion. Individuals having a poor zinc status absorb zinc more efficiently than those with a good status (Whittaker, 1998). Zinc absorption involves a carrier mediated component as well as a non-mediated diffusion component. The carrier mediated component is the component most severely influenced by other micronutrients. Factors that may influence the zinc absorption include other minerals, trace elements, proteins, vitamins, phytic acid, physiological factors and disease processes.

Although vitamin C is known to influence the absorption of other minerals, this has not been seen with zinc absorption. According to Sandström (2001), studies done by Spencer in 1984, indicated that calcium does not seem to have a direct effect on zinc absorption because these two elements are absorbed by two different transport mechanisms. Absorption studies in humans suggest that the effect of calcium on zinc availability at nutritionally relevant concentrations is less evident and that calcium addition may even improve zinc absorption from phytate containing foods (GLV). A negative interaction between calcium and zinc however is possible at higher calcium intake, as consumed through supplements (Sandström, 2001). Zinc deficiency could consequently impair folate bioavailability, because the polyglutamine forms of dietary folate require the conjugation by a zinc-dependent hydrolase prior to intestinal absorption. It has also been suggested that folate could impair zinc absorption. Zinc deficiency leads to mucosal dystrophy, which could reduce absorption, not only of the polyglutamine forms of folate, but also of other nutrients. A poor zinc status will also affect the utilisation of vitamin A, because zinc containing proteins are needed for the release of vitamin A from the liver and for the tissue metabolism of vitamin A (Sandström, 2001).

The availability of zinc from the diet can be improved by reduction in the phytate content (present in GLV) of the diet and inclusion of animal protein sources such as mutton. The phytate content can also be reduced by activating the phytase present in most phytate containing foods through the addition of microbial or fungal phytases. Phytases hydrolyse the phytate to lower inositol phosphate, resulting in improved zinc absorption (FAO/WHO, s.a.).

Zinc and Folic acid

It has been proved that there exists an inverse relationship between folic acid intake and zinc at intestinal levels. In charcoal-binding studies it was indicated that zinc transport is significantly decreased when folate is present in the intestinal lumen (Ghishan, Said, Wilson, Murrel & Greene, 1986). Similarly folic acid transport is decreased in the presence of zinc. In the presence of folate, the mucosal zinc content significantly decreases, while folate transport decreased in the presence of zinc chloride concentrations in the lumen of the gastrointestinal tract (Ghisan *et al*., 1986). Folic acid supplements influence zinc homeostasis, probably through formation of insoluble chelates and impairment of absorption. It has been proved that folic acid supplementations form stable complexes with copper and iron, but do not influence the absorption of these specific minerals in the body (Milne, Kanfield, Mahalko & Sandstead, 1984). Zinc and folate do not form insoluble compounds at a pH level of 6 as was first thought to be the reason for the effect on the absorption. It is thought that zinc and folate may form complexes in the low pH of the stomach, but these complexes dissolve once they reach the higher pH of the duodenum (Ghisan *et al*, 1986). The mineral interactions in food are minimal, and are mainly affected by supplements of the respective micronutrients.

Zinc and Copper

Copper has little effect on zinc absorption, although long term ingestion of large quantities of zinc (supplements) can interfere with copper absorption. Cases of microcytic hypochromic (signs of copper deficiency) anaemia after long-term zinc supplementation have been reported. It has been suggested that long-term vitamin C supplementation may impair the absorption of copper and thereby counteract the positive effect on iron absorption. The effects of ascorbic acid on copper absorption are, however, not conclusive. The zinc–copper interaction probably takes place at the absorption level and high zinc intakes only marginally decrease copper absorption (Sandström, 2001). Zinc and copper found in GLV does not interact as interactions are only evident at high mineral content levels such as in the case of supplementation.

Iron and Zinc

Due to the fact that iron is the most common nutritional deficiency in the world, and zinc deficiency leads to poor growth and development, fortification and supplementation of these two minerals is becoming more common daily worldwide (Whittaker, 1998). The widespread use of iron fortification and supplementation makes any interaction between iron and other micronutrients of special nutritional relevance (Sandström, 2001). Several studies showed that high iron concentrations

negatively affect zinc absorption when these minerals are given in solution (Whittaker, 1998). Zinc and iron interact competitively during intestinal absorption. When both nutrients are ingested simultaneously in aqueous solutions at levels commonly used in supplements, there is evidence that an excess of iron inhibits zinc absorption and that excess zinc inhibits iron uptake.

In a study done on the influence that iron supplements might have on the absorption of zinc and copper, it was thought that iron might inhibit the intestinal zinc and copper uptake, because these elements may compete for binding to a transporter molecule (divalent metal transporter 1) that is located on the apical side of the small intestinal epithelium. After the completion of this study it was clear that oral iron therapy (supplements) decreases zinc absorption and thus zinc status, but does not affect copper absorption. Iron supplementation increases the risk of developing or maintaining zinc deficiency because iron decreases zinc absorption in humans in a dose-dependent way when given in a water solution but not when given with a meal (Troost *et al*., 2003). In the presence of food based substances iron and zinc are absorbed by different mechanisms and the risk of interactions is larger when the nutrients are provided as supplements (Sandström, 2001) thus emphasising the great advantages associated with food based programmes rather than supplements. Population groups with higher zinc requirements, such as infants, adolescents, and pregnant and lactating women, may be more sensitive to an iron–zinc interaction (Sandström, Davidsson, Cederblad & Lonnerdal, 1985).
The mechanisms by which this interaction between zinc and iron takes place seem to be that after reduction by ferric reductase, ferrous iron (2+) crosses the apical membrane of the gut by binding to the transporter protein DMT1 (Andrews, 1999). Furthermore, DMT1 also transports other divalent cations such as zinc and copper. DMT1's expression is regulated by the iron concentration in the epithelial cells of the small intestine. A decrease in DMT1 expression may be the cause of the decreased zinc absorption in the proximate small intestine (Troost *et al*., 2003). Figure 2 illustrates how iron binds to DMT1 to be transported across the epithelial cells of the small intestine.

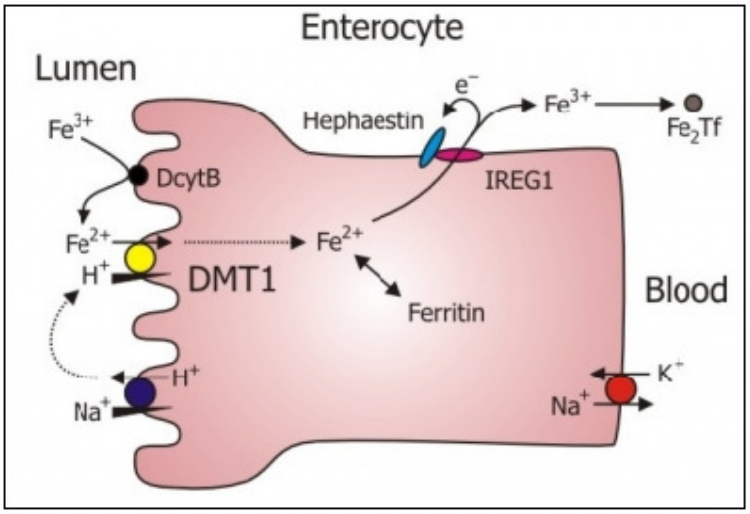

FIGURE 2: Intestinal iron absorption through DMT1 (Mackenzie & Hediger, 2004)

Similar to the iron–zinc interaction, zinc in high doses in aqueous solutions impairs iron absorption, while no effect is observed when zinc is consumed during meals (Sandström *et al*., 1985). When zinc and iron are consumed in a meal there doesn't seem to be any interaction between these two minerals, and both minerals are absorbed (Donangelo, Woodhouse, King, S.M., Viteri & King, J.C., 2002). Thus in a meal containing both GLV and mutton, both good sources of iron and zinc, the optimal amount of minerals will be absorbed as there will be no inhibition of minerals.

Vitamin A

Carotenoid and vitamin A absorption depends on various factors, including the food matrix, the processing conditions of the food and the fat content of the meal (Figure 3) (Williams & Erdman, 1996). Fat is required at three points in the absorption of vitamin A. Firstly fat stimulates the secretion of bile, secondly it plays a role in the formation of mixed-micelle, and lastly in the formation of chylomicrons. Without sufficient fat, vitamin A absorption is limited (Williams & Erdman, 1996). The importance of fat in the absorption of vitamin A can clearly be seen in Figure 3, as fat plays a role at various steps in vitamin A absorption. Carotenoids found in GLV's such as spinach are bound by proteins and fibrous regions in the chloroplast. Chopping, mild heating, chewing and digestive enzymes aid in denaturing these binding proteins in order to release the entrapped carotenoids (Williams & Erdman, 1996). Adequate protein and zinc status is required for the absorption of vitamin A (Williams & Erdman, 1996). Vitamin A can enhance nonheme iron absorption and thus contribute to increasing haemoglobin levels (Sanström, 2001).

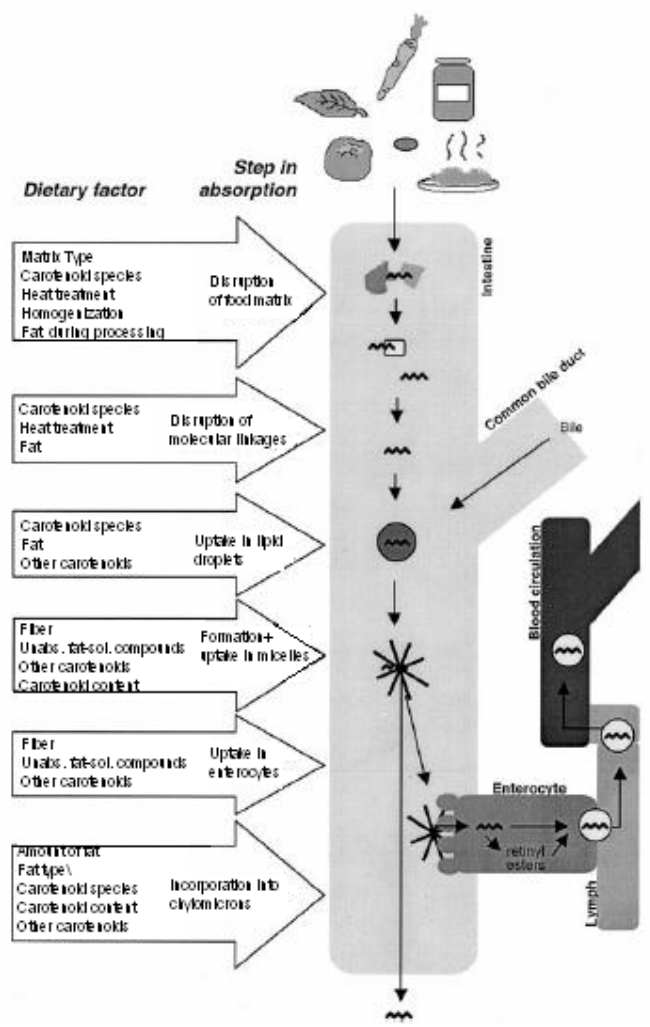

FIGURE 3: Dietary factors affecting carotenoid absorption (Van het Hof, West, Weststrate & Hautvast, 2000)

CONCLUSION

Some diseases commonly found in South Africa are related to malnutrition (under- and overnutrition), thus emphasising the need for greater knowledge on the composition of food (Johnson, 1987) as well as the micronutrient interactions of foods (Hallberg, 1998). Detailed knowledge on the composition of food is essential to understand the function of nutrients in the diet. Although the potential of plant food towards controlling iron deficiency in developing countries such as South Africa has been proposed, the bioavailability of nonheme iron in plant foods is low and plant foods often contain a variety of compounds such as tannins, phytates and polyphenols that inhibit the absorption of nonheme iron (De Pee, West, Muhilal, Karyadi & Hautvast, 1996).

The nutrient contributions and benefits of consuming red meat and GLV (Table 5) in combination to the body hold numerous benefits. From an overnutrition point of view; Cosgrove, Flynn and Kiely (2005) explain that the reason why diets high in red meat are associated with increased risks of coronary heart diseases, diabetes and obesity is the fact that these high protein diets usually contain low amounts of vitamin C and fiber. Combining GLV which contain high amounts of ascorbic acid (vitamin C) and fibre with a diet containing red meat may therefore be beneficial. From an undernutrition point of view; low income communities usually limit their food purchases by choosing less meat or less expensive meats containing more fat and bone (Leibtag & Kaufman, 2003). The fat content of red meat can enhance the nutrient bioavailability as fat is required for the absorption of the fat-soluble vitamin A found in GLV (Williams & Erdman, 1996). Fat stimulates bile flow and acts as a carrier for this hydrophobic nutrient. Without sufficient fat, the chylomicrons will not be formed and the vitamin A will be left in the mucosal cells (Williams & Erdman, 1996).

Table 5: Comparison of nutrient content of a 100g portion of green leafy vegetable and edible mutton portion.

Micronutrients	Unit	Green Leafy Vegetable [1] (mean)		Mutton (C2) [2]	
		Raw	Cooked	Raw	Cooked
Protein	g	4.54	3.7	20.5	26.8
Fat	g	0.24	0.12	8.98	11.6
β-carotene	µg	2716	1353	[3]	[3]
Vit C	mg	5.55	3.4	[3]	[3]
Riboflavin	µg	0.07	0.05	0.04	0.07
Thiamine	µg	-	-	0.04	0.02
Zinc	mg	0.88	0.72	3.66	4.26
Iron	mg	11.4	9.56	2.84	3.26

[1] The mean of the four green leafy vegetables described in Table 1 and Table 2
[2] Results from current study (mean of 100g raw and cooked edible portion)
[3] Not determined as do not make a significant contribution to the diet
\- Not available

The data used in Table 4 is derived from the mean of the values of four green leafy vegetables commonly consumed namely amaranth, spinach, radish leaves and cabbage. Mutton contains almost six times more protein than GLV (Table, that on the other hand contains significant amounts of the B-vitamins (41.75µg) compared to that present in mutton (0.04µg). Utilization of β-carotene from GLV (Table 4) is poor when consumed raw and without added fat (Williams & Erdman, 1996; Underwood, 2000). According to De Pee and West (1996), increased vegetable consumption on its own, has no effect on vitamin A status, and therefore ingestion of fat along with carotenoids is crucial. An addition of 3-5g fat can have a beneficial effect on the absorption of carotenoids (Van het Hof *et al.*, 2000). These results emphasise the benefits of consuming these two food products in combination. When studying Table 4 it is clear that GLV contain 1,6% of the zinc that can be found in mutton and mutton contains forty times more iron than GLV. The bioavailability of the iron in the mutton has not been determined; however, literature shows that heme iron present in meat is highly absorbable when

compared to iron from plant origin. 100g cooked GLV consumed with 100g cooked mutton will be a source of protein, β-carotene, vitamin C, vitamin B_1 and B_2, zinc and iron.

Food-based approaches, targeting the relief of iron deficiency, usually encourage the consumption of animal foods together with the consumption of GLV, because of the high bioavailability of heme iron in animal foods (Ruel, 2001). Non heme iron (found in GLV) absorption is influenced by soluble enhancers and inhibitors consumed during the same meal. Factors known to enhance nonheme absorption in the body include unknown factors present in meat and organic acids such as ascorbic acid, citric acid, malic acid and lactic acid enhance the absorption of iron (Kumari *et al*., 2003; McWilliams, 2005). There is the possibility that other consumed foods may interact with GLV, resulting in enhanced or reduced absorption of micronutrients. Considering the value of GLV and mutton as a double fortificant of both iron and beta-carotene in the present, results in a good reason to emphasize their importance in populations as affordable and natural sources of iron and beta-carotene.

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6

CONCLUSION AND RECOMMENDATIONS

Due to the increased focus and consumer demand for lean meat, the quality of meat has become a focus point in the meat industry. This demand emphasises the importance of physical composition data for all meat carcasses as well as the respective cuts. However, the physical composition and nutrient content of SA mutton (C2) have never before been determined. The current data on mutton (lamb and sheep) that appears in the Medical Research Council's (MRC) food composition tables of 1999 is derived from the United States Department of Agriculture (USDA) database (Sayed, Frans & Schönfeldt, 1999).

The physical composition and nutrient content of SA lamb (A2) has been determined previously in a study at the ARC:LBD (Van Heerden, 2007). With the availability of the nutrient content of age class C and fatness level 2 data, it is possible to compare the nutrient composition of lamb (A2) with mutton (C2) and study chronological changes.

This study on the physical composition of the South African mutton carcass indicates that 63.2% of the carcass consists of muscle with fat that contributes 16.9% to the total carcass composition. South African mutton carcasses contain higher amounts of intermuscular fat (9.16%) than subcutaneous fat (7.78%). Comparing the current result with published data (Kempster, Croston & Jones, 1987), it is clear that there are significant differences between South African mutton (C2) and those of the UK.

As animals grow older, weight increases until mature size is reached (growth phase) and the body composition and shape change (developing phase). According to Berg and Butterfield (1978), the muscle to bone ratio increases during initial growth (increase in weight of the animal). Callow (1948) reported that fatty tissue grows at a greater rate followed by muscle (meat) and then bone, during the fattening period of growth in sheep, so that the proportions of both tissues decrease in a regular manner as fat increases. According to Wiese, Pethick, Milton, Davidson, McIntyre and D'Souza (2005) age class C carcasses are heavier and contain higher percentages of fat than younger age classes. This is apparent in the current study which indicates that mutton (C) contains 28.8% more fat than lamb (A) carcasses (Table 1) from the same subcutaneous fat class of 2.

TABLE 1: Physical carcass composition of South African mutton (C2) and lamb (A2)

	Mutton (C2) (% of total carcass weight)[2]	Lamb (A2) (% of total carcass weight)[1]
Average weight of carcass	28-30kg	18-20kg
Bone	20.3	20.2
Meat (muscle + intramuscular fat)	62.7	66.2
Total Fat:	17	13.2
of which intramuscular	*9.3*	*7.4*
of which subcutaneous	*7.7*	*5.8*
Total:	100	99.6

1 Van Heerden, 2007
2 Current study, 2008

Nutrients vary between the raw and the cooked cuts due to moisture loss. Several micronutrients are lost during the cooking process through leaching and solubility in cooking liquids. South African mutton (C2) can be regarded as an important dietary source of the B vitamins, iron, and zinc. The current study found that cooked South African mutton (C2) contains 4.9g less fat and 30.5mg less cholesterol per cooked 100g edible portion than previously published in MRC tables. These new results show that the leg cut of mutton (C2) could qualify for the Heart Foundation mark of approval as it contains less than 10g fat per 100g edible portion. If the loin and shoulder cuts (C2) are trimmed from subcutaneous fat, as is a common practise in many upper income households, these cuts will contain less than 10% fat and could then also qualify for the Heart Mark Foundation.

The same experimental study was used for the nutrient analysis of the mutton as the lamb. The mutton and lamb cuts were cooked to the same internal temperature in the same labs. Due to the similarity of the methods used in these two studies the results are comparable. During cooking, both mutton and lamb cuts lost moisture which resulted in an increase in protein. When the nutrient content of lean lamb (A2) is compared to that of mutton (C2) the different age groups contain similar amounts of protein (25.01–30.9g / 100g) (Sayed *et al.,* 1999). As can be seen in Table 2, it is clear that lamb (A2) contains more fat than mutton (C2) although the fat percentage in lamb is higher in cholesterol. Younger animals contain higher amounts of cholesterol due to the developing phases of body composition in sheep. Cholesterol is found in the cell membrane and younger animals have higher quantities of small cells per 100g (Berg & Butterfield, 1978). The fat content of the lamb decreased during cooking while the fat of the mutton increased with 2,6g.

Cooked mutton is a richer source of iron (3.26mg/100g) than lamb (0.63mg/100g) and cooked beef (A age, 4% fat), (1.99mg / 100g), (Schönfeldt, Visser, Van Niekerk & Van Heerden, 1996). Higher iron content in mutton is mainly due to the iron stores in the older animal (Schönfeldt *et al.*, 1996).

TABLE 2: Comparison of the nutrient composition for raw and cooked 100g edible portion of South African lean lamb (A2) and South African mutton (C2)

Nutrients analysed	Unit	Raw		differences between studies	Cooked		Differences between studies
		Lamb (A2)[1]	Mutton (C2)[2]		Lamb (A2)[1]	Mutton (C2)[2]	
PROXIMATE ANALYSIS:							
Moisture	g	71.5	73.8	-2.3	65.4	64.6	0.83
Protein (Nx6.25)	g	18.3	20.5	-2.2	25.1	26.9	-1.73
Fat	g	9.01	8.98	0.0294	8.44	11.6	-3.16
Ash	g	2.88	1.19	1.69	1.07	1.16	-0.09
Food energy (calculated)	kJ	644	679	-35	745	889	-144
MINERALS:							
Magnesium (Mg)	mg	20.1	22.2	-2.12	21.7	22.8	-1.06
Potassium (K)	mg	291	265	26.4	298	274	23.77
Sodium (Na)	mg	83.4	86.5	-3.08	71.3	73.5	-1.15
Zinc (Zn)	mg	2.25	3.66	-1.41	1.72	4.25	-2.53
Iron (Fe)	mg	0.96	2.84	-1.88	0.63	3.26	-2.63
VITAMINS:							
Thiamin (B_1)	mg	0.10	0.04	0.06	0.04	0.02	0.02
Riboflavin (B_2)	mg	0.09	0.04	0.05	0.05	0.07	-0.02
Niacin (B_3)	mg	1.47	4.96	-3.49	1.42	2.99	-1.57
Pyridoxine (B_6)	mg	0.40	0.20	0.20	0.12	0.11	0.01
Cyanocobalamin(B_{12})	µg	3.54	2.37	1.17	0.93	0.10	0.83
LIPIDS: Saturated fatty acids (SFA)							
14:0	g	0.57	0.25	0.32	0.82	0.32	0.50
16:0	g	2.22	2.29	-0.07	4.59	2.96	1.63
18:0	g	1.46	1.94	-0.48	2.89	2.68	0.21
20:0	g	0.02	0.02	0	0.0	0.03	-0.03
Monounsaturated fatty acids(MUFA)							
16:1	g	0.19	0.15	0.04	0.62	0.19	0.43
18:1	g	3.43	3.62	-0.19	8.04	0.29	7.75
Polyunsaturated fatty acids (PUFA)							
18:2	g	0.27	0.22	0.05	1.21	0.28	0.93
Cholesterol	mg	62.8	50.3	12.48	103	62.5	40.5

1 Van Heerden, 2007
2 Current study, 2008
- Indicates that the lamb (A2) has less of the particular nutrient than mutton (C2)

Mutton and lamb contain a wide range of nutrients, in different concentrations, that contribute to its important place in a healthy diet. From the results it is clear that South African mutton and lamb is low in fat and cholesterol and is a good source of iron and zinc and the B vitamins. South African lamb (A2) qualifies for the Heart Foundation, containing less than 10g fat per 100g edible portion while the mutton (C2) carcasses contain just too much to qualify for this foundation.

These results indicate that South African mutton (C2) is an excellent source of protein, iron, zinc and vitamin B_3 as it makes a valuable contribution to the RDA of these nutrients for males, aged 25 – 50 years when included as part of a balanced meal plan. Therefore, it can be recommended that lean mutton meat can be consumed in moderation and form part of a healthy balanced diet.

Consuming red meat (lamb or mutton) in combination with green leafy vegetables (GLV) may have a beneficial effect in decreasing iron and vitamin A content in lower income communities. This food

based strategy results in an improved micronutrient absorption in the human body. The potential of plant foods contributing towards controlling iron and vitamin A deficiency in developing countries such as South Africa has been queried previously. The nutrient contributions and benefits of consuming red meat and GLV in combination to the body hold numerous benefits. Utilization of β-carotene from GLV is poor when consumed raw and without added fat (Williams & Erdman, 1996; Underwood, 2000). According to De Pee and West (1996), increased vegetable consumption on its own has no effect on vitamin A status, and therefore ingestion of fat along with carotenoids is crucial. An addition of 3-5g fat can have a beneficial effect on the absorption of carotenoids (Van het Hof, West, Weststrate, & Hautvast, 2000). These results emphasise the benefits of consuming these two food products in combination.

Food-based approaches, targeting the relief of iron deficiency, usually encourage the consumption of animal foods together with the consumption of GLV, because of the high bioavailability of heme iron in animal foods (Ruel, 2001). Considering the value of GLV and mutton as a double fortificant of both, iron and vitamin A, results in a good reason to emphasize their importance in populations as affordable and natural sources of iron and beta-carotene.

Considering the fact that significant differences were apparent between the current study and previous data published in the MRC tables, it is important that further analysis on nutrient composition of SA products in order to increase the validity of the SA food composition tables. It is recommended that the Red Meat Industry support further analysis of SA mutton (C2) in order to obtain the nutrient results on all the cuts, as only three cuts were analysed in this study. It is also recommended that the effect of cooking temperature on vitamins be considered in future studies

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APPENDIX A: FORM USED FOR PHYSICAL COMPOSITION DATA – Mutton (C2)

ANIMAL: _____ Slaughter date: _____

Number: _____ Freezing date: _____

Mass of carcass on arrival: _____kg_

Mass of side before cutting: _____ **Left side** or **Right side** (circle)

Cut no.	Cut (kg)	Starting mass (kg)	Bone (kg)	Subcu-tanecous fat (kg)	Inter muscular fat (kg)	muscle (meat & intra-muscular fat) (kg)	Total calculated (kg)
1.	Neck/nek						
2.	Thick rib/Dikrib						
3.	Flank/lies						
4.	Shoulder/blad						
5.	Breast/ribbetjie						
6.	Rib/rib						
7.	Loin/lende						
8.	Chump/kruis						
9	Leg						
10.	Shin/skenkel						

Subcutaneous and inter-muscular fat together

Intra-muscular fat is part of the meat sample