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The quality of South African lamb – carcass, nutrient and sensory attributes

by

Salomina Maria van Heerden

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by

Salomina Maria van Heerden (née Jerling)

Dissertation submitted to the
Faculty of Natural and Agricultural Sciences
Department of Consumer Science
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Supervisor: **Prof. H.C. Schönfeldt**

Co-supervisor: **Dr P.E. Strydom**

Co-supervisor: **Dr R. Kruger**

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

……………………. ………………..

S.M. van Heerden **Date**

ABSTRACT

The quality of South African lamb – carcass, nutrient and sensory attributes

by
Salomina Maria van Heerden

Supervisor: Prof. HC Schönfeldt
Co-supervisor: Dr PE Strydom
Co-supervisor: Dr R Kruger

Department of Consumer Science
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University of Pretoria

For the Philosophiae Doctor Degree in Consumer Science

The aim of the study was to determine the quality of South African lamb, particularly the carcass, nutrient and sensory attributes. To this end the cut composition of SA lamb carcasses with different fat scores was determined and cuts suitable for trimming were identified. Sixty four grain fed Dorper lambs were divided randomly into three slaughter groups of 30, 36 and 42 kg, respectively. After slaughter, electrical stimulation (how much/long) and chilling (how long/temp) the carcass sides were subdivided into seven wholesale cuts. Each cut was dissected into meat, bone and subcutaneous fat (SCF) in order to determine the physical composition per cut and for the whole carcass. It was found that the percentages total fat in the carcass increased with 15.5 % in subcutaneous fat over the five fat classes.

In order to determine and compare the raw and cooked nutrient composition of shoulder, loin and leg cuts of Dorper and Merino lamb carcasses of the A age class of fat class 2 (± 7 % SCF) from three main production areas in South Africa were analysed. Samples were analysed both raw (left side cuts) and cooked (right sides) using accredited methodologies for nutrient content namely proximate composition, vitamin B and minerals. There was no significant difference in the iron and zinc values between the cooked cuts. Results showed differences in both trace elements and B vitamins among different cooked cuts, although the differences were not statistically significant. Cooked SA lamb (A age class, fat class 2) contains an average of 60.5 % less total fat and 5.28 % less protein, resulting in 1891 kJ less per 100 g edible portion energy, if compared to the previous values in the food composition tables.

Quantitative descriptive sensory analyses were performed by a trained panel on the *M. longissimus lumborum* (loin) from lambs of the same age. Aroma intensity, initial impression of juiciness, first bite, sustained impression of juiciness, muscle fibre and overall tenderness, amount of connective tissue (residue), overall flavour intensity and off-flavour intensity were measured, as well as cooking related measurements and resistance to shear. With the exception of juiciness, the results in this study showed that contrary to expected carcass fatness (in the same age over five fat classes), as portrayed in the South African Classification system, does not have a significant effect on the sensory qualities of *M. longissimus lumborum* (loin) from lambs of the same age.

This investigation provides important scientific insight into the physical, nutrient and sensory quality of South African lamb. The results obtained show that subcutaneous carcass fat that increased significantly with an increase in fat class can be trimmed to represent leaner cuts to the discerning consumer. This study found unique values for South African lamb cuts, almost 40 % lower in fat content than the previously-believed-to-be-accurate values, as published by the Medical Research Council for health workers. Contrary to expected it was found in this study that increased fatness did not improve lamb tenderness as popularly believed in the United States. Therefore, the study justifies greater scope for further research into all these aspects, as it provides valuable information for the Red Meat Industry.

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Especially to my husband George, my sincere gratitude for your love, encouragement, patience and support through these years.

Finally, I dedicate this study and my career to HIM who made it all possible with the following:

……” Psalm 139”..

…. “U is, omdat U is
Ek is, omdat U daar is.
Alles is deur Hom en vir Hom geskep,
en niks word toevallig ontdek.” ……

Kowie Rossouw & Randall Wicomb
2004

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ABSTRACT

The quality of South African lamb – carcass, nutrient and sensory attributes

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The need for information on the quality of South African lamb and mutton to address consumer uncertainties was identified by the Red Meat Producers Organisation (RPO) who requested that the quality of South African lamb be investigated. The aim was to determine the quality of South African lamb, namely the carcass, nutrient and sensory attributes. However, due to financial constraints, only the most often consumed cuts of the most popular grade (A2) were analysed for nutrient content.

In South Africa, sheep carcasses are classified subjectively according to age and amount of fat cover. The consumer is concerned about fat in the diet and consequently certain local meat companies have altered part of their operations to boneless retail cuts that could include trimming of fat off cuts to obtain and market a leaner, more attractive cut for the consumer. The objectives were, firstly to determine the cut composition of SA lamb carcasses with five different fat classs, and secondly to identify certain cuts that are suitable for trimming. The study consisted of 66 pasture-fed Dorper lambs that were divided into three groups and slaughtered at 30, 36 and 42 kg live weight. Chilled carcass sides were subdivided into seven wholesale cuts and dissected into meat bone and subcutaneous fat (SCF) in order to determine the physical composition per cut and

for the whole carcass. The soft tissue of the carcass was analysed for total fat, protein, ash and moisture. According to the result, the percentages total fat in the carcass increased with 15.5 % over the five fat classes, with the largest increase (26 % units) in the loin cut followed by the flank, shoulder and neck cut. The % meat (lean) of the neck, thick rib and breast showed no significant change between fat class 1 to 5, although the % bone decreased significantly (> 6 % units). Meat and bone proportions decreased significantly with increase in fat class for the loin, flank, leg and shoulder cuts. The composition of the loin cut was most affected overall by changes in the fat class. Trimming reduced the boneless SCF level of the loin, leg and shoulder by 12, 6 and 9 % units, respectively, when trimmed from a fat class 5 to a fat class 3. Further trimming to fat class 1, reduced the % SCF by 18, 8 and 5 % units on a boneless level. The SCF of the neck and thick rib could be reduced significantly between 4 and 5 % units from fat class 5 to fat class 3. The neck, thick rib, breast and flank cuts could be trimmed significantly from a fat class 3 to a fat class 1 level by 5 % units. Although trimming could be applied to the over fat carcass and cuts within the fat class, the cost of the process as well as possible profit on the end product should be considered.

The right sides of Dorper and Merino lamb carcasses of the A age class, fat class 2 (± 7 % SCF) from three main production areas in South Africa were used to determine the raw and cooked nutrient composition of three cuts (shoulder, loin and leg). Nutrients showing the greatest differences between raw and cooked treatments, were protein, total fat, cholesterol, C16:0 saturated fatty acids (SFA) and C18:1n9c monounsaturated fatty acid (MUFA). Moisture losses due to cooking resulted in an increase in the protein and cholesterol concentrations of the cooked cuts. Iron content was lower in the cooked loin cut but increased in the cooked leg cut when compared to the corresponding raw cuts. The vitamin B content of all three cooked lamb cuts was lower, although not significantly, than that of the corresponding raw cuts. Therefore, lamb is a good source of protein, iron and the B vitamins, especially vitamin B12 in cooked meat.

The effect of fat class (carcass fatness) on sensory quality, shear force and cooking loss was determined on the M. longissimus lumborum (loin) of Dorper lambs. Quantitative descriptive sensory analysis, were performed by a trained panel, evaluating the meat for aroma intensity, initial impression of juiciness, first bite tenderness, sustained impression of juiciness, muscle fibre and overall tenderness, amount of connective tissue (residue), overall flavour intensity and off-flavour intensity. Two of the eight sensory attributes differed significantly ($p < 0.05$), namely, initial impression of juiciness and sustained juiciness, with a positive correlation existing between initial impression of juiciness and sustained impression of juiciness. A strong positive correlation was found between the amount of connective tissue (residue) and firste bite tenderness as well as between the amount of connective tissue (residue) and tenderness. No significant differences were found for any of the texture attributes between the five fat classes. Total cooking loss had a high positive correlation with total drip loss and fat mass. Cooking losses and juiciness were influenced by the amount of fat present on the M. longissimus lumborum (loin) cuts however, aroma, flavour and tenderness were not affected by the degree of fatness.

Results of the study indicate great scope for further investigation and research on all cuts of all fat classes that will provide valuable information to the meat industry, health workers and consumers on the physical, nutritional and sensory attributes of South African lamb. However, more research is needed to evaluate consumer acceptance of individual lamb cuts with operations to trim excess fat as a marketing strategy and to positively alter consumer perception of lamb products. The South African consumer will have to be informed about the physical, nutritional and sensory attributes of lamb and therefore the role of marketing in this regard cannot be over-estimated.

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OPSOMMING

Die kwaliteit van Suid Afrikaanse lamsvleis – karkas-, voedings- en sintuiglike eienskappe

deur

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Universiteit Pretoria

Vir die Doktorsgraad in Verbruikerswetenskap

Die behoefte aan inligting ten opsigte van die kwaliteit van Suid Afrikaanse lamsvleis is deur die Rooivleis Produsente Organisasie (RPO) geïdentifiseer met die einddoel om verbruikers onsekerheid aan te spreek en derhalwe versoek dat die kwaliteit van Suid Afrikaanse lamsvleis ondersoek word. Die doel van die studie was om die kwaliteit van Suid Afrikaanse lamsvleis, naamlik die karkas-, voedings- en sintuiglike eienskappe te bepaal. As gevolg van finansiële beperkinge is slegs die A2 klas geanaliseer aangesien dit die mees algemeen verbruik word.

Suid-Afrikaanse skaap karkasse word geklassifiseer volgens ouderdom en vet klasse. Omdat die kwessie van vet in die dieet belangrik is vir die verbruiker, het die plaaslike vleishandelaars reeds gedeeltes van hul produksie aangepas om ontbeende snitte met 'n moontlikheid van vet afranding te bemark met die oog op maerder vleissnit. Die doel vir die karkasevaluering tydens die studie was om die omderskeie snit samestelling vir vyf vetklasse te bepaal en tweedens om snitte te identifiseer vir moontlike afranding van die onderhuidse vetlaag (OHV) van Suid Afrikaanse lamsvleis. Die studie het bestaan uit 66 veld gevoerde Dorper skape wat in drie groepe ingedeel is en geslag is op onderskeidelik 30, 36 en 42 kg. Die verkoelde karkasse is verdeel in sewe groothandelsnitte waarna elke snit verdeel (gedissekteer) is in vleis, vet en been om sodoende die fisiese snit- en karkassamestelling te bepaal. Chemiese analise is gedoen op die vleis en vet van elke snit. Die resultate toon 'n algemene toename van 15.5 % totale vet oor die vyf vetklasse, met die grootste toename (26 % eenhede) in die lendesnit gevolg deur die lies-, blad- en neksnitte. Daar was geen betekenisvolle verskille tussen die nek-, dikrib- en borssnitte se % vleis toename oor die vyf vetklasse nie, in teenstelling met 'n beduidende afname (6 % eenhede) in die % been. Die verhouding vleis en been het 'n beduidend afname getoon met die toename oor die vet klasse vir die lende-, lies-, boud- en bladsnitte. Die lende snit is die meeste beïnvloed deur die toename in vet klasse. Tydens die afranding van die onderhuidse vet van 'n vetklas 5 na vetklas 3 op die ontbeende lende-, boud- en bladsnitte, het die vet persentasie onderskeidelik met 12, 6 en 9 % afgeneem. Verdere afranding tot 'n vetklas 1 het die onderhuidse vet persentasie onderskeidelik verlaag met 18, 8 en 5 % eenhede. Die onderhuidse vet persentasie van die nek-, en dikribsnitte kon suksesvol verlaag word met 4 - 5 % van 'n vet klas 5 tot 'n vetklas 3. Verder kon die nek-, dikrib-, bors- en liessnitte afgerand word van 'n vetklas 3 tot 'n vetklas 1 met 5 % eenhede. Alhoewel afranding op beide die oorvet karkas asook snit binne dieselfde vetklas gedoen kan word, moet die koste van die proses en die moontlike winste op die eindproduk oorweeg word.

Die regtersye van Dorper en Merino lamkarkasse met 'n A ouderdom en vetklas 2 (± 7 % OHV) van drie hoof produksie areas in Suid Afrika is gebruik om die rou- en gaar voedingswaardeanalise van drie snitte (blad, lende en boud) te bepaal. Die grootste verskil tussen die rou en gaar analise is waargeneem vir die konsentrasie proteïne, totale vet, cholesterol en die hoeveelheid poli- en mono-onversadigde vetsure C16:0, C18:1n9c. Die toename in die konsentrasie proteïen en cholesterol kan toegeskryf word aan vogverlies tydens die gaarmaakproses. Ysterinhoud van die gaar lendesnit was laer as die van die gaar boudsnit. Die vitamine B inhoud van al drie gaar snitte was laer in vergelyking met die van die rou snitte alhoewel nie betekenisvol nie. Lamsvleis kan dus beskou word as 'n goeie bron van proteïene, yster en B-vitamines, veral vitamine B_{12} in gaar lamsvleis.

Die invloed van vetklasse (toename in vetheid) op die sintuiglike eienskappe, sagtheid (snyweerstand) en gaarmaakverlies, van die M. longissimus lumborum (M.LL) is ondersoek. 'n Opgeleide proepaneel is gebruik om die kwaliteits eienskappe te evalueer, naamlik aromaintensiteit, geurintensiteit, aanvanklike- en voortgesette sappigheid, sagtheid, hoeveelheid fibreuse weefselresidu (bindweefsel), algemene geur en die intensiteit van die nasmaak. Slegs twee van die kwaliteits eienskappe het betekenisvol ($p < 0.05$), van mekaar verskil tussen die vetklasse, naamlik, aanvanklike en voortgesette sappigheid. Daar was 'n hoë verwantskap tussen die hoeveelheid fibreuse weefselresidu (bindweefsel) en eerste indruk van sagtheid asook tussen die hoeveelheid fibreuse weefselresidu (bindweefsel) en sagtheid. Geen verskille is waargeneem vir enige tekstuur eienskappe tussen die vyf vetklasse nie. Daar was 'n hoëverwantskap tussen die gaarmaakverlies en die drupverlies asook die vetinhoud van die snitte. Die gaarmaakverlies

en sappigheid hou verband met die hoeveelheid vet teenwoordig in die lende snit M. longissimus lumborum (M.LL), alhoewel die aroma-, geurintensiteit en sagtheid nie beïnvloed is deur die vetheid nie.

Resultate van die studie toon die moontlikheid vir verdere ondersoek en navorsing van al die snitte in al die vetklasse wat waardevolle inligting aan die vleisindustrie , gesondheidswerkers asook aan die verbruiker sal voorsien. Verdere navorsing ten opsigte van verbruikers aanvaarbaarheid en bemarkings strategie is egter nodig ten opsigte van die afranding van 'n oormaat onderhuidse vet vir sekere lamsvleissnitte. Hierdie bemarkings aspek moet nie ligtelik opgeneem word nie aangesien dit belangrik is dat die verbruiker behoorlik ingelig word ten opsigte van die karkas-, voedings en sintuiglike eienskappe van Suid Afrikaanse lamsvleis.

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
ASTM	American Society for Testing and Materials
CSIR	Council for Scientific and Industrial Research
FAO	Food and Agriculture organization of the United Nations
g	gram
GC	Gas Chromatography
HPLC	High Performance Liquid Chromatography
IC	Ion Chromatography
IMF	Intermuscular fat
INQ	Index of nutritional quality
kJ	kiloJoules
kcal	kilocalories
kg	kilogram
LMY	Lean meat yield
LSD	Least significant difference
MIC	Meat Industry Centre
MLA	Meat and Livestock Australia
M.LL	Muscles longissimus lumborum
MRC	Medical Research Council
mg	milligram
MUFA	Monounsaturated fatty acid
NCD	Non-communicable diseases
NERPO	National Emerging Red Meat Producers Organisation
NRIND	National Research Institute for Nutritional diseases
PC	Principal Component
PCA	Principal Component Analysis
RDA	Recommended Dietary Allowances
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
SAMM	South African Mutton Merino
SANAS	South African National Accreditation Services
SCF	Subcutaneous fat
SFA	Saturated fatty acid
%	Percentage
UK	United Kingdom
US	Unites States
USA	United States of America
µg	Microgram
WHO	World Health Organization

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Ina van Heerden (Salomina Maria)

Ina van Heerden matriculated in 1980 at Verwoerdburg High School in Centurion. She obtained a HED Home Economics qualification in 1985 from the University of Pretoria. In December 1985 she joined the Agricultural Research Council.-Irene and as Head Agricultural Research Technician at the Agricultural Research Council, her specific project responsibilities include research on the nutrient content and sensory analysis of South African beef and poultry and have been awarded a tender by the Red Meat Research Developing Trust to continue the research on the nutrient content of South African lamb and mutton. She was awarded an M Tech degree in Food and Nutrition in 1999 from Tswane University of Technology and received the ARC Director's merit award for Technician-of-the-Year in 2000.

In her thesis, **The quality of South African lamb - carcass, nutrient and sensory attributes** the promovendus investigated the carcass composition, macro- and micro-nutrient content and sensory profile of South African lamb. The carcass composition data show the variation in subcutaneous fat of the various cuts of the carcass at different fat levels and trimming can be positively implemented to provide a more palatable and leaner product to the consumer. The nutrient analyses found unique values for South African lamb cuts, almost 40 % lower in fat content than the previously-believed-to-be-accurate values, as published by the Medical Research Council for health professionals, consumers and the food industry. Contrary to expected it was found in this study that increased fatness did not improve lamb tenderness as popularly believed in the United States. To date the results of the thesis have been presented at two international and two local conferences, as well as three papers of which one has already been accepted for publication.

Supervisor	Prof. H.C. Schönfeldt
Co-supervisor	Dr P.E. Strydom
Co-supervisor	Dr R. Kruger
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1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION AND LITERATURE REVIEW

Most developing countries face the consequences of both nutritional deficiencies and excesses and South Africa is no exception. They are all subjected to the double burden of persisting undernutrition in the midst of the growing epidemic of obesity and non-communicable diseases such as cancer and heart disease (Labadarios, 2000:3).

According to Schönfeldt (2005:13), chronic undernutrition affects some 215 million people in sub-Saharan Africa, or 43 percent of the population. According to the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO), an estimated 206 million people in Africa are iron deficient; 86 million are affected by iodine deficiency, and up to 31 million are deficient in vitamin A. Labadarios (2000:3) confirmed that a double burden of nutrition-related diseases is prevalent in many households and communities in Southern Africa, as both over- and undernutrition are experienced, due to rapid urbanization and acculturation. Schönfeldt (2005:13) noted that numerous South Africans suffer from the health-implications of inappropriate diets, with obesity being the most underlying nutritional disease in causing many of the major non-communicable diseases. This forms part of the massive global burden of diet-related diseases that drives consumers not only to improve their health through optimized nutrition, but to improve their health through positive eating and problem treating. As the incidence of chronic diseases continues to increase, the consumer's interest in the positive role food can play in controlling these afflictions, is growing. Schönfeldt (2003:1) furthermore mentioned that individuals are moving from efforts to optimize balanced nutrition, to acting in order to improve their health resulting in the concept of "food today for medicine tomorrow".

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, 1999:8). From a health perspective, consumers are concerned about the amount of fat and cholesterol food products contain, as well as the long term effect it has on their well-being. Sañudo, Enser, Campo, Nute, Maria, Sierra and Wood, (2000:339) reported that too much visible fat discourages the consumer and it is often removed either before cooking or during the meal, especially by the younger consumer. The amount of fat in the diet and its saturated fatty acid content are considered major risk factors for coronary heart disease (Sañudo *et al.,* 2000:339). Eating quality, price and safety are the other major factors the consumer considers when making a food choice. However, various other influences such as cultural acceptability, family income, symbolic status, food security, social status and society are recognized as contributing to these food choices (Shepherd & Sparks, 1994:203).

As consumers are increasingly more focused on the quality and nutritional characteristics of meat and meat products, fresh meat has been referred to as the food in which consumer confidence has decreased the most during the nineties (Verbeke, 1999:8). This could be attributed to the fact that many organizations including consumer organisations, industry, producers and government have been involved in debates on the issues of fat and cholesterol, growth hormones and price, to name but a few (Verbeke, 1999:8). Diseases such as foot-and-mouth disease, notifiable Avian Influenza and Bovine Spongiform Encephalopathy (BSE) have also impacted on consumer confidence in considering meat to be as safe (McCarthy & Barton, 1998:14).

Research on South African meat quality and more specifically on meat production was initiated at the Animal and Dairy Science Research Institute of the Department of Agriculture and Water supply in 1968. In 1973 a small abattoir with a few laboratories were erected and have been used since. Additional laboratories and a sensory evaluation unit were added in 1977. The initial programme involved meat production studies including carcass and muscle characteristics of cattle and sheep. In the early 1980's the Institute focused on and conducted investigations into the classification and grading of all red meat-producing species. This accommodates the carcass and meat quality requirements for consumers and meat producers. The classification of beef and lamb carcasses resulted in major adjustments to the official carcass grading system in 1981, and is still being used today (Meat Science Centre, s.a.). During this time a need for information on the quality attributes of all red meat products arose and was identified as a top priority. To this end, a major study was completed on the nutritional value of different classes of beef in the South African Meat Classification System (Schönfeldt, 1998).

In 2003, the need for information on the quality of South African lamb and mutton to address consumer uncertainties was identified by the Red Meat Producers Organisation (RPO) as being of prime importance, following similar studies in Australia by the Meat and Livestock Australia (MLA). They subsequently requested that the quality of South African lamb be investigated. In 2004, the study was undertaken by the Agricultural Research Council-Animal Nutrition and Animal Products Institute (ARC-ANPI). The aim was to determine the quality of South African lamb, in terms of the carcass, nutrient and sensory attributes. However, due to financial constraints, only the most often consumed cuts of the most popular class (A age class, fat code 2) were analysed for nutrient content.

Sheep and goat numbers slaughtered in South Africa have declined from 8 505 000 in 1991/1992 to 5 042 000 in 2004/2005 (The Directorate: Abstract of Agricultural Statistics, 2005:64). The same trend was observed for South African lamb consumption, which declined from 5.2 kg per capita in 1991/1992 to 2.7 kg per capita in 2004/2005 (The Directorate: Abstract of Agricultural Statistics, 2005:64). Therefore there is a unique opportunity for growth in this sector of the South African meat market.

South Africa is a country that has been renowned for sheep production for own consumption since the early 1900's. Small ruminants (sheep and goats) form an integral part of smallholder farming systems in South Africa and make a significant contribution to the total farm income, stability of the farming system and nutrient intake (Cloete, Hoffman, Cloete & Fourie, 2004:44). This is in contrast to the commercial sheep industry which competes against other animal protein sources such as beef, pork, poultry and fish for delivering an affordable product to the consumer. 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 lamb products (Shackelford, Leymaster, Wheeler & Koohmaraie, 2003:1).

In South Africa, lamb carcasses are classified according to age and fat class. This assists both the industry and consumer to choose the product that they best prefer. According to the Agricultural Product Standards Act No. 119 of 1990 and its regulations, (National Department of Agriculture, 1990:9-14), the classification system is designed to describe carcasses according to tissue composition and age. Age is described according to the number of permanent incisors, with age class A = 0 teeth, AB = 1-2 teeth, B = 3-6 teeth and C = more than 6 teeth, while carcasses are grouped into six fat classes by means of visual appraisal (fatness class from 0 = no fat, to 6 = excessively over-fat). According to the fatness classification (National Department of Agriculture, 1990:9-14), an A age class, fat code 2 lamb may have at least 1 mm, but not more than 4 mm fat cover, over the loin or 5.6 % but not more than 8.5 % subcutaneous fat (SCF). The South African classification system provides the basis for assisting the untrained consumers in the selection of meat cuts to contribute to health and to provide eating satisfaction (SAMIC, s.a.). It also assists the meat traders to describe their specific requirements in simple terms when purchasing carcasses and to utilize a variety of cuts with specific fatness levels in the market with the goal of optimum consumer satisfaction. It furthermore helps to contribute to a price structure for selling meat (SAMIC, s.a.).

Carcass composition

Carcasses of meat animals are composed primarily of proportions of muscle, fat and bone of which muscle is the most important part contributing to the diet of all people (Cloete *et al.,* 2004:44). The composition of fatness and muscling of lamb carcasses varies due to differences in gender, age, breed, and slaughter weight, although fat content is the most important quality criteria in the cooled carcass, as weight is used to set the carcass price (Díaz, de la Fuente, Lauzurica, Pérez, Velasco, Álvarez, Ruiz de Huidobro, Onego, Blázquez & Cañeque, 2005:61; Cunhal-Sendim, Murillo, Belenguer

& Castello, 1999:190-191). According to Johnson, Purchas, McEwan and Blair (2005:383), the value of a lamb carcass is mainly determined by the lean meat yield (LMY %) as excess fat is economically inefficient. Therefore, the major aim in any animal production system with regard to carcass quality should be to produce a carcass with the highest edible yield. The most valuable parts of the carcass are the loin and legs. The hind leg and loin contribute to the higher priced cuts of the carcass, because these cuts are less associated with fat and connective tissue (Sheridan, Hoffman & Ferreira, 2003:63).

Recently, more attention has been paid to U.S. consumer behaviour and attitude towards meat due to demographic, psychographic and ethnic forces (Veblen, 1988:129), which impact on meat consumption. These are worldwide, major issues, affecting the meat sector (Verbeke & Viaene, 1999:437). Once the desired cut is known, the product (cut) can be utilized by the industry to ensure that the consumer has a quality product - primal cuts with consistent size, colour, fat content and value for money. Marketing the right animal in South Africa, and presenting the desired cut with the most nutritious assets, contributes to promoting and increasing the consumption of lamb. Retailers will have the ability to provide a product that is low in fat content. However, certain cuts may need to be trimmed while others may fall within consumer's specification for fatness.

Knowledge of the carcass (physical) composition is necessary to provide the preferred cut as such or by further trimming of the cut to the consumers' preference (Hopkins, Watton, Gamble, Atkinson, Slack-Smith & Hall, 1995:34). Furthermore, these authors stated that retailers would be able to offer a diverse range of nutritious, lean cuts to the consumer. The composition of tissue, especially the lean meat proportion of South African lamb and mutton is of great importance, because it will make it possible to assign nutritional and economical value to the carcass (Hopkins *et al.,* 1995:39). Therefore, the ability to promote the nutritional attributes of lamb to the consumer is considered important to improve the health-related perceptions of lamb.

Nutritional importance of lamb

As consumers are conscientious about what they eat, the health aspect of food is important. For the health professionals and workers to guide the consumer, information regarding the nutritional value of food, in this case SA lamb is important and necessary. Therefore, as in many other countries, South Africa is actively involved in analysing food for the compilation of food composition data tables.

It is important for different countries to have their own food composition tables for meat products such as lamb, mutton, beef and pork. The reason for this is that different techniques are used to cut carcasses into primal cuts in the different countries. Different age groups and fat codes of the animals in various countries make the interpretation of the results difficult (Schönfeldt, 1998:4) as the composition of the carcasses has a direct influence on the nutrient content thereof. The difference in climate, soil content and water composition of the various regions and countries also affects the nutrient content (specifically the minerals and vitamins) of the animal feed, as well as the production of vitamin D in the meat itself (Greenfield and Southgate, 2003:69).

TABLE 1: NUTRIENT VALUES IN LEAN LAMB PER 100 G COOKED EDIBLE PORTION OF SELECTED COUNTRIES

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

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

Table 1 provides a comparison of macro- and micronutrients when different data sources are used, and illustrates that the use of different food composition tables may cause conflicting interpretation of dietary intake data. Iron content of meat is positively correlated with age of the animal (Lawrie, 1998:62). Variation is evident in the total fat content and this could be due to various factors such as intensive finishing or differing cutting up techniques between countries and that visible subcutaneous and intermuscular fat are included in cuts such as loin chops (Enser, Hallett, Hewett, Fursey, Wood & Harrington, 1998:339).

The Medical Research Council (MRC) is responsible for compiling South African food composition tables (Langenhoven, Kruger, Gouws & Faber, 1993:1). These tables are used in dietary surveys, nutritional intervention research, nutrition education, catering, consumer information, etc. The Research Institute for Nutritional Diseases (NRIND) issued the first food composition tables in 1991.

However, these tables did not include unique values for South African meat products, but consist of data obtained mainly from American and English composition tables and this is not readily applicable to the South African context.

Only 18 % of the foods in the 1991 MRC Food Composition Tables were authentic South African data (Langenhoven *et al.,* 1993:1). At a national symposium in September 1995, it was agreed that a national effort was necessary to compile food composition data for South Africa. A National Steering Committee for South African Food Composition Data (SAFCOD) was consequently formed in November 1995 with the aim to drive and promote a national food composition database. The 1999 MRC Food Composition Tables of South Africa was revised and the database has been increased with local South African data for vegetables, beef, chicken, fruit and dairy to 41 % (Langenhoven *et al.,* 1993:1). The nutrient content of 59 % of the food consumed daily in South Africa is largely estimated or extrapolated from foreign data (including the data on South African lamb) (Codjia, 2000:41). According to Cobiac, Droulez, Leppard and Lewis (2003:133) accurate nutrient composition data are essential communicating nutrition information to consumers and therefore it was priority to analyse the nutrient composition of South African lamb.

Cameron (2004:49) noted that the world is consuming less red meat now than it did 40 years ago. A study into the per capita consumption of red meat found that South Africans consumed 40 kg of red meat annually in 1960 but only 19 kg a year in 1990.

A South African national meat consumption survey was conducted by ACNielsen (2001). Personal at-home interviews with structured questionnaires (translated into six languages) were used in an area-stratified, probability sample of 2481 SA households. Results showed that 55 % of the consumers ate chicken, 36 % beef, 16 % lamb, 11 % fish and 4 % of the consumers ate pork at least three times a week, whereas 10 % of the consumers never eat lamb/mutton. Furthermore, ACNielsen (2001) reported that the older generation consumers (50+ years) showed a greater decline in consumption of red meat in comparison to the younger generation and that this could be attributed to the price as well as a belief that eating red meat aggravates and causes “affluent diseases” such as heart disease. Consumers perceived lamb and mutton to be expensive and considered it to be high in cholesterol. Poultry was rated to be the most nutritious meat source (60 %), followed by fish (49 %), beef (39 %) and lamb (32 %) (ACNielsen, 2001). Consumers preferred lean meat with minimum fat required for flavour and juiciness (Ward, Trent & Hildebrand, 1995:69). The quality and quantity of fat are important because consumers are more and more interested in healthy products and therefore prefer lean meat and carcasses (Cunhal-Sendim *et al.,* 1999:190-191).

Innovative methods where boneless, fat-trimmed (even the intermuscular seam fat) sub-primals are presented to retailers, were suggested by Garrett, Savell, Cross and Johnson (1992:1829, 1836) to enable them to supply attractive retail cuts. In Australia, (Hopkins *et al*., 1995:34) the introduction of the “trim lamb” range of cuts with boneless, fat-trimmed cuts and even muscle separation within primal cuts were preformed under the Prime Lamb Program. These cuts complied with Australian National Heart Foundation guidelines of a total fat content < 10 % per edible portion.

In South Africa, certain meat retailers started to change at least part of their operations to boneless retail cuts, although fatness is mostly controlled by restriction of carcass fatness and trimming is not generally performed (Just Lamb, 2004). Adjusting these operations to trim excess fat will not only result in a more acceptable product, but will also enable processors to use carcasses of various fat classes, thereby broadening the basis of supply. However, trimming is costly and this could potentially add to the high cost of sheep meat and it is therefore necessary to have an estimate of the fat yield of the different primal cuts. In addition, as different cuts accumulate fat at different rates, information of fat accumulation of cuts over different fat classes (fat levels), needs to be known in order to select the leaner cuts and carcasses to be processed for the consumer. The challenge is to ensure that high yield traits are not promoted at the expense of eating quality. A small amount of fat is desirable to increase and sustain tenderness and decrease the risk of the meat drying out, but too much fat decreases the retail cut yield. It should be noted that unknown to the consumer, red meat has become less fatty over the years (10 % for lamb) through new breeding, feeding and trimming techniques (Williamson, Foster, StanNer, & Buttriss, 2005:10-13) and in itself has started to affect palatability (Cameron 2004:49). However, consumers are more willing to compromise taste for a product that is perceived to be healthier, therefore nutrition, fat level and cholesterol affects meat consumption, (Ward, Trend & Hildeband, 1995:65).

Sensory characteristics

According to Veblen (1988:129) the six components important to the consumer when choosing meat, is convenience, price, nutrition, variety, quality and good taste. The human senses have been used for centuries to evaluate the quality of foods (Lawless & Heymann, 1998:6). Because the SA consumer consumes meat frequently as part of their diet and enjoys the product, quality and sensory attributes such as tenderness and overall flavour are important (ACNielsen, 2001). Texture, aroma and flavour characteristics are the main criteria used by consumers to evaluate the sensory quality of meat (Gorraiz, Beriain, Chasco & Iraizoz, 2000:137). These sensory attributes can be measured objectively by a trained panel, using descriptive techniques. Descriptive sensory evaluation addresses the complexity of food systems by taking into account as much food sensory attributes or flavour notes as possible (Brovelli, Brecht, Sherman, Sims & Harrison, 1999:707). Descriptive methods focus on the intensities of sensory characteristics of a product such as aroma, juiciness, flavour and tenderness (Lawless & Heymann, 1998:367).

Sensory evaluation has been defined by the Institute of Food Technologists (IFT) (1975) as "a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch and hearing".

Sensory analyses are sophisticated tools and are often the final step in the evaluation of various treatments of meat and other food products (Lawless & Heymann, 1998:341). Sensory analyses form an essential part in determining the quality of meat and profiling of food because these sensory factors of taste, aroma and texture contribute to the palatability of meat (Nevison & Muir, 2002:559). Results obtained during sensory evaluation can provide valid and reliable information with regard to a product's sensory properties (profile). It will eventually provide insight regarding the position of a product, relative to other competitive products in the current market on which sound decisions can be made by the meat industry (Lawless & Heymann, 1998:1).

Although the perceived healthiness of a food is of great importance for consumer preference (Fisher, Enser, Richardson, Wood, Nute, Kurt, Sinclair, & Wilkinson, 2000:141), one of the most important aspects of eating quality for meat that determines overall acceptability is texture (tenderness) (Risvik, 1994:67). Factors affecting muscle and meat tenderness have been extensively researched over the past 70 years and according to Dransfield (2001:74), tenderness is the primary determinant of the acceptability and eating quality of meat. Meat tenderness is a very complex characteristic of meat quality, as it is biologically dependent on factors such as species, age, fat code, gender, the retail cut chosen, the method of cooking, and muscle type (two protein fractions, namely connective tissue and myofibrillar properties) (Dransfield, 2001:74). Furthermore, tenderness is determined by conditions during the early p*ost mortem* period and includes factors such as electrical stimulation, aging, chilling temperature, cooking method, and cooking time, internal and end-point temperature of the meat (Lawrie, 1998:194). Where sensory evaluation is a subjective evaluation method, Warner-Bratzler shear force measurements give an objective measurement of tenderness which is used in research laboratories to evaluate relative differences in tenderness or toughness of meat products. A low shear force value (measured in kg force) indicates that less force is required to shear through the sample and therefore the meat is tender. Generally the overall shear force values reported in the literature (Duckett, 2001:22) for lamb are lower than most beef values. According to Duckett (2001:22), the threshold values (cut-off point for toughness) in beef, for shear force (broiled chops, cooled and four half-inch cores) is considered to be around 4.5 kg. Values below 4.5 kg (threshold) indicate that consumers could rate it slightly tender or better for the overall tenderness. No published values are available for lamb yet, but based on shear force values reported for beef, it appears that consumers would consider similar lamb shear force values acceptable for palatability (Duckett, 2001:22).

Flavour is an important sensory characteristic for the overall acceptability of meat products (Shahidi, 1996:1). According to Woods (1998:603), the sensation of flavour is the result of a combination of responses on the tongue, and in the mouth, throat and nose. Bett (1993:122) reported that many flavour descriptors for cooked meat are the same for all species e.g. brothy / meaty, but there are species-specific characteristics such as "porky, beefy or muttony", made up of several factors including odour and taste. Lamb flavour is primarily an aromatic flavour described as fragrant, oily, fatty, sweet and somewhat musty, a blend of many chemical compounds present when lamb is cooked (Jeremiah, Tong & Gibson, 1998:234). Young, Reid, Smith, and Braggins (1994:80) reported that it is believed that as animals grow older; their meat becomes more strongly flavoured because sheep become fatter as they age. They also reported that fat tends to accumulate in subcutaneous depots rather than intramuscularly or around organs. Since fats are strongly implicated in mutton odour it seems reasonable that the increased fattiness alone may be important in odour (Young, *et al.,* 1994:81).

Both the quality and quantity of fat in meat products are important to the consumers who are becoming more and more interested in healthy choices and prefer lean meat and carcasses (Cunhal-Sendim *et al.,* 1999:190-191). Consumers demand tender, lean meat with the minimum fat required for flavour and juiciness (Ward *et al.,* 1995:96, 70). The South African classification system provides the basis for assisting untrained consumers in the selection of meat cuts with positive health attributes and eating qualities. It also assists the meat traders to describe their specific requirements in simple terms when purchasing carcasses, for utilization in a variety of markets, with the goal of optimum consumer satisfaction by providing products and meat cuts that address different needs of the consumer.

The aim of this research is to contribute valuable data to the South African consumer concerning the quality of South African lamb, particularly with regard to the carcass, nutrient and sensory attributes.

MOTIVATION FOR THE STUDY

The most important challenge facing mankind in the future is to provide adequate nutrition and safe food as well as clean water for all in an environmentally safe way (Vorster & Houtvast, 2002:9). Globally, nutrition is recognised as a major determinant of a wide range of diseases of public health importance. Today, most developing countries face the consequences of both nutritional deficiencies and excesses and are subjected to the double burden of persisting undernutrition in the midst of a growing epidemic of obesity and non-communicable diseases (NCD) such as cancer and heart disease (Shetty, 2002:329). In developing countries, numerous deficiency diseases continue to exist, especially in rural communities, due to essential nutrient deficiencies in the daily diet. Increasingly these now co-exist with the presence of diet-related chronic diseases previously only seen in developed countries (Schönfeldt, 2005:13). 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.

It is clear that meat plays a prominent role in the diet of many people and this proposed study will make a significant contribution to the understanding of its composition. Presently there is little scientific information available on the carcass composition and nutrient content of South African sheep meat (lamb and mutton). Although it can be argued that since South African sheep meat (lamb and mutton) all originated from international genotypes and that their composition should therefore be similar, both national and international experience in Australia, Europe and the United States found unique values when analysed, due to different climate, feed, genotype and classification systems. The difference in the cutting up of the carcasses between the various countries also makes the interpretation of their results limited due to the composition of meat and fat for these cuts (Schönfeldt, 1998:4). Furthermore, animals in South Africa are slaughtered at different slaughter weights and fatness percentages than in other countries, this limits the utilization of their results, as these factors have a direct influence on the nutrient content of the carcass. Greenfield and Southgate (2003:50) stated that differences in climate, soil content and water composition in South Africa will also affect the nutrient content of the animal feed (specifically the minerals and vitamins) as well as the production of Vitamin D in the meat itself. The physical composition of an animal, changes as it matures and ages (Micol, Robelin & Geay, 1991:54, 68).

Consumers are increasingly more focused on the quality and nutritional characteristics of meat and meat products. Fresh meat in particular has been referred to as the food in which consumer confidence has decreased the most during the last decade, due to its perceived contribution to the amount of fat in the diet and its content of saturated fatty acids. These are considered to be major risk factors for coronary heart disease (Sañudo, *et al.* 2000:339).

For consumers to make appropriate choices in respect of nutrition, it is necessary to understand the nature of nutritional problems. Nutrition (what we eat and drink) is a complex social issue, which requires action across a broad front. McCance and Widdowson (1940:5), defined nutrition as: *"A knowledge of the chemical composition of foods that is essential in the dietary treatment of disease or in any quantitative study of human nutrition"*. The food choices one makes influence the individual body's health positively or negatively and therefore each day's choices may harm or benefit one's health. Although food intake is also shaped by a variety of other factors such as pleasure, culture, traditions, religion and other social and economic reasons, the eating quality, price and safety are the major factors considered when making a food choice (Dransfield, 2001:76).

With the correct analysis and interpretation of the carcass composition of South African lamb the nutrient content and quality characteristics of South African lamb can effectively be marketed to address the negative health image that lamb and mutton has. A study conducted on the quality of goat and sheep meat by Schönfeldt (1989:209) confirmed that meat of younger animals (irrespective of species) is juicier, more tender and contains less connective tissue, residue and that typical species-characteristic flavours are less typical than those of older animals. When the correct data on the nutrient content of South African lamb 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.

The consumer should be able to make a more informed choice when purchasing and consuming lamb if the new information on the quality attributes, carcass and chemical composition as well as the vitamin, mineral, cholesterol and fatty acids are known. Therefore, the aim of the study is the first step in building up a scientific data bank on the nutrient content, carcass and quality attributes of South African lamb.

STRUCTURE OF THE DISSERTATION

The dissertation is presented in the form of articles, according to the following chapters:

CHAPTER 1:	Introduction and literature review
CHAPTER 2:	Research design and methodology
CHAPTER 3:	The influence of fat score and fat trimming on primal cut composition of South African lamb
CHAPTER 4:	Nutrient content of South African lamb (A2 class)
CHAPTER 5:	Effect of fatness on meat quality of the loin cut of SA Dorper lamb
CHAPTER 6:	Discussion, conclusions and recommendations

In the following chapters the style and layout, as prescribed by the Journal in which the article will be published has been followed. Chapter 3: South African Journal of Meat Science.
Chapter 4: Journal of Food Composition and Analysis.
Chapter 5: Journal of Sensory Studies.

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 research objective formulated for this study was to determine the quality of selected raw and cooked wholesale cuts of South African lamb – carcass, nutrient and sensory attributes.

The specific objectives were:

1. To determine the carcass and cut (physical) composition of seven raw wholesale cuts of South African lamb of the A age class, representing five of seven fat classes.
2. To determine the nutrient content of the boneless portion of three selected raw and cooked wholesale cuts (leg, loin and shoulder) of South African lamb (A age, fat class 2 with an average of ± 7 % subcutaneous fat).
3. To determine the effect of fatness on meat quality (sensory attributes) of the loin cut of South African Dorper lamb.

Assumptions

1. The left side of each carcass was considered to be identical to the **right** side.
2. The trained sensory panel evaluated each sample objectively and consistently.
3. Once the methods and techniques had been standardized during the preliminary study, each meat sample was treated identically throughout the project.

Null hypothesis (H_0)

There will be no significant differences in the carcass, nutrient and sensory attributes of selected raw and cooked primal (wholesale) cuts of the A age class of South African lamb, when compared to current local South African and international data.

Alternative hypothesis (H_1)

There will be significant differences in the carcass, nutrient and sensory attributes of selected raw and cooked primal (wholesale) cuts of the A age class of South African lamb when compared to existing and international data.

PURPOSE OF THE STUDY

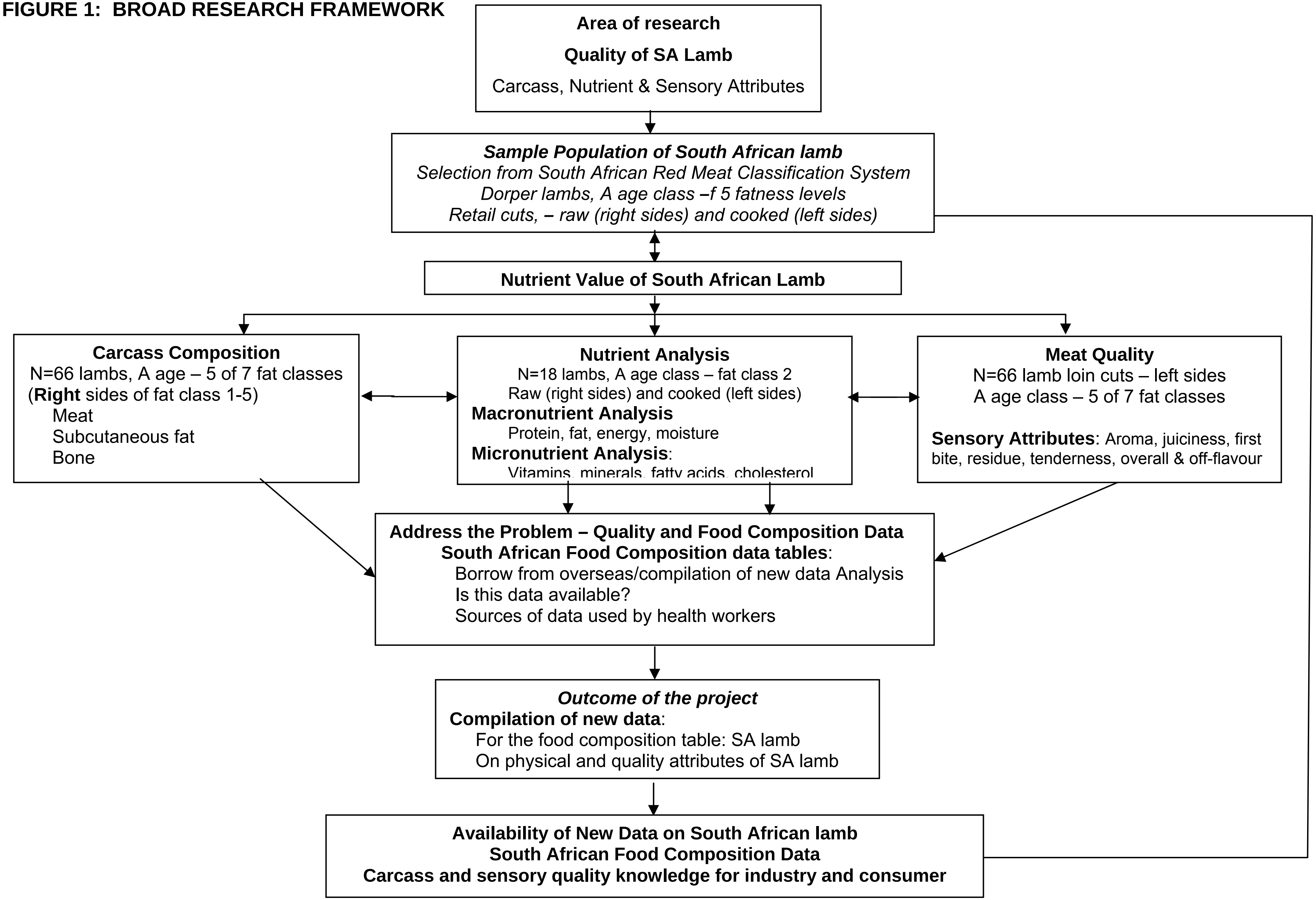
The purpose of the study was to describe the quality of South African lamb in terms of carcass, nutrient and sensory attributes. When the data of the nutrient content is incorporated into South African food composition tables, it will serve as a reliable standard reference to the users of these tables. The data will provide useful information to the red meat industry, the producers, the retail industry and consumers.

EXPERIMENTAL DESIGN

The framework indicates the steps that were followed during the process of data collection, in an attempt to answer the research objectives posed. The design (Figure 1) clearly indicates the steps, methods and procedures of sampling, measurements, data-collection and data-analysis that were followed throughout the study in order to execute the study.

The research design can be described as an empirical design using an exploratory approach. It addresses the “what is the case?” and “what are the key factors?” and focuses on primary data.

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 (also see Chapters 3, 4 and 5). These concepts were defined as follows:

Lamb and mutton

Lamb is the red flesh (muscle) of sheep slaughtered at a young age with white fat, a milder taste and finer texture than mutton. Mutton is the flesh of sheep older than 6 months also referred to as sheep meat. It has a deep red to purple colour and a stronger flavour with a coarser texture than lamb.

Sample (sample population)

For this study, sample refers firstly to the animals that was selected namely A age class, fatness 1-5. Secondly it refers to the individual retail (wholesale) cuts that were selected and thirdly, to the three portions it was dissected in to viz. lean (meat), fat and bone.

South African Red Meat Classification System for lamb and sheep

The Red Meat Classification System is especially designed to make the purchase of red meat (beef, lamb, sheep and goat) as simple as possible for customers. The main characteristics used to classify beef, lamb (for this study), sheep and goat carcasses, are the age of the animal and the fatness of the carcass. No actual age according to months can be given, as the age of these animals is determined by the number of permanent incisor teeth - the more permanent incisors, the older the animal. The age of an animal is considered to be an indication of the tenderness of the meat - the meat of younger animals is more tender than that of older animals.

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). The roller mark on a carcass includes the age class (AAA, ABA, BBB or CCC) and the fatness class (000 (no fat), 111 (very lean), 222 (lean), 333 (Medium), 444 (fat), 555 (Over fat) or 666 excessively fat)). When referring to the class of a carcass, both the age class and fatness class are implicated (SAMIC s.a.).

According to the fatness classification of sheep, (National Department of Agriculture, 1990:9-14, in SAMIC s.a), the seven fat classes are described as follows:

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 A age class and fat class one to five of seven. No animals from the zero and six fat class were included.

Carcass (physical) composition

The carcass composition done 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 plus inter- and intramuscular fat), fat (subcutaneous) and bone. Physical composition refers to either the carcass or the cut composition.

Subcutaneous fat (SCF) and Intermuscular fat (IMF)

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, 1980:85). Intermuscular fat (IMF) was not analysed for this study but 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, 1980:85).

Nutrition

Nutrition is the science of foods and nutrients and the other substances they contain (Whitney & Rolfes, 2002:3, 5).

Nutrients

Nutrients are chemical substances in or obtained from food and are used in the body to provide energy, structural materials and regulating agents to support growth, maintenance and repair body tissue. Nutrients may also reduce the risk of some diseases (Whitney & Rolfes, 2002:3, 5).

Nutritional value

Nutritional value could be an indication of the quantity of a specific nutrient and its absorption or bioavailability of the nutrient from the food item (West & Schönfeldt, 2002:258). In this study the nutritional value (profile of nutrients) for three wholesale cuts were examined.

Nutrient analysis

To determine the quantity of macro- and micronutrients in a sample. The macronutrients analysed (also called proximate analysis) for this study were the percentage water (moisture), fat, protein (N x 6.25 = protein) and ash (minerals). They were determined according to AOAC methods (2005). The energy (kJ / 100 g) for meat was calculated using the percentage protein multiplied by 17, plus the percentage fat, multiplied by 37 (Greenfield & Southgate, 2003:146). The micronutrients determined for this study were certain water soluble vitamins, minerals, fatty acids and cholesterol. The proximate analyses were done on the wholesale cuts (raw and cooked). No fat-soluble vitamins were analysed due to budget constraints.

Nutrient content

Nutrient content refers to the variety of nutrients and their bioavailability in a food product (lamb meat). 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, 2002:3, 5).

Nutrient composition

The nutrient composition of the food sample (in this case, lamb) consists of different levels of vitamins (fat- and water-soluble), minerals, fatty acid profile, total cholesterol and amino acid profile (total protein content).

Raw and cooked samples

For this study, the terms can be defined as follows: Raw means that the meat is fresh and frozen and has not been exposed to heat. Cooked means, that meat has been processed by exposing it to heat. According to Paul and Palmer (1972:395) heat changes the composition of meat, due to the denaturation and coagulation of proteins, melting of fat, alterations in pH and in water-holding capacity as well as in chemical changes in heat labile compounds.

Dry heat cooking method

It is the process that takes place when the meat is cooked without added water and with no lid on the pan so that moisture from the meat can evaporate. Roasting, broiling, pan broiling and frying are all dry heat cooking methods. Dry heat cooking methods are usually used for tender cuts of meat (Charley, 1986:406).

Moist heat cooking method

Is the process where by meat is cooked in a covered utensil (saucepan, foil wrapping, or cooking bag), whether or not water is added, or the meat is cooked in the steam or liquid which is released from the meat as the protein coagulates. Braising and boiling in water are moist heat cooking methods. This cooking method is recommended for less tender cuts of meat (Charley, 1986:409; Cross, 1988:162).

Primal (wholesale) cuts for lamb and mutton

In the South African meat industry, a sheep carcass is usually subdivided into the following primal (wholesale) cuts: neck, thick rib, flank, shoulder, breast rib, loin, chump, leg and shins (shank) and thereafter into retail cuts by the retailer. For this study the carcass was divided into the following seven wholesale cuts: neck, shoulder (plus shin), thick rib, breast, leg (plus shin), flank and loin. A large number of methods exist whereby carcasses (sheep) can be jointed (cut up). In the past, various efforts have been made to provide an internationally accepted, technical description of sheep carcasses. These studies have, however, been hampered by differences in consumer habits, in the definition of joints, in dissection methods and cooking methods (The cuts of a beef carcass, 1981:1). These differences occur between countries, or due to personal preferences and individual butchers, as well as consumer habits of the population groups in various geographical and economical areas.

Meat quality

Meat quality is a comprehensive concept with different components that affect consumer decisions when purchasing meat. Relevant to this study is:

Carcass composition, visual appraisal - factors associated with classifying.

Eating quality: sensory attributes namely aroma, juiciness, tenderness and overall flavour.

Nutrient quality: proportions protein, vitamins and minerals relative to energy density and their biological availability (SAMIC, s.a.).

Food composition tables

This is also referred to as the food composition database and consists 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: 264). The tables are organized according to the classification of foods into food groups (West & Schönfeldt, 2002: 250-251). From this study, the nutrient value of three raw and cooked lamb cuts will be available to be included in the South African food composition tables.

EXPERIMENTAL DESIGN

MATERIALS AND METHODS

Sheep meat is produced in all the regions of South Africa, except the far northern areas. Since South African lamb is mostly produced on natural pastures in semi-arid areas, certain breeds were specifically developed for these conditions. The two most important sheep breeds in South Africa are the Dorper and Mutton Merino breeds (SAMIC, s.a.)

The Dorper breed, a white-bodied sheep with a black head, was developed in the 1940's, in the Karoo region of South Africa, by crossing the imported Blackhead Persian (a fat-rumped hair breed that is adapted to harsh arid environmental conditions) and the British Dorset Horn (Snowder & Duckett, 2003:368). The Dorper breed is currently the second largest breed in South Africa and has spread throughout the world. A live weight of about 36 kg can be achieved by the Dorper lamb at the age of 90 - 120 days (3 - 4 months), with a carcass weight of approximately 16 kg (Breeds of livestock, 1999:1).

The South African Mutton Merino breed is a dual-purpose (mutton and wool) sheep breed, which was developed from an imported German Merino breed. It has adapted to most environmental conditions of South Africa. It was bred specifically to produce a slaughter lamb at an early age (35 kg at 100 days of age) and at the same time produces good volumes (4 kg) of medium to strong wool (Breeds of livestock, 1999:1). The breed is characterised by a high growth rate and produces slaughter lambs with good meat quality attributes (Neser, Erasmus & Van Wyk, 2000:172).

The lamb meat samples incorporated into this study, comprised of the most commonly consumed carcasses in South Africa (Van der Westhuizen, personal communication, 2003), namely the Dorper breed. Sixty six Dorper male and female animals from five fat classes were selected from two different abattoirs that slaughter carcasses for three production areas in South Africa namely the Karoo, Kalahari and Ermelo districts.

SAMPLE AND SAMPLE PREPARATION

In this study lambs were raised intensively to different levels of carcass fat, to investigate the pattern of fat accumulation in different cuts, in accordance with the separation of carcasses in the South African classification system. Different groups of animals were drawn for various sections of the study, depending on the availability of funding.

Carcass composition

Sample for carcass composition

Sixty six lambs (males and females) with an initial weight of between 23 - 26 kg were divided into three groups with equal mean weights (Table 1). The animals were randomly allocated to three slaughter groups (viz. 30, 36 and 42 kg). They were grain-fed fed in individual pens (1.5 m x 1 m) and slaughtered when reaching the target weight (30, 36 and 42 kg) in each slaughter group were on average, 90 - 120 days (4 - 6 months) old. All the male animals were slaughtered pre-puberty and no secondary male development had yet occurred. For this study the carcass was divided into seven wholesale cuts: neck, shoulder and shin, thick rib, breast, leg and shin, flank and loin.

TABLE 1: EXPERIMENTAL DESIGN FOR EVALUATION OF CARCASS AND CHEMICAL COMPOSITION OF SOUTH AFRICAN LAMB

<table>
<tr><td>Breed type</td><td colspan="5">Dorper</td></tr>
<tr><td>Number of animals in study</td><td colspan="5">66</td></tr>
<tr><td>Starting weight (kg)</td><td colspan="5">23 - 26</td></tr>
<tr><td>Days on feed</td><td colspan="5">90 – 120 days (4 - 6 months)</td></tr>
<tr><td>Slaughter weight (kg)</td><td colspan="2">30</td><td>36</td><td colspan="2">42</td></tr>
<tr><td>Number of animals in slaughter group</td><td colspan="2">20</td><td>24</td><td colspan="2">20</td></tr>
<tr><td>Distribution of carcasses per fat class</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td></td><td>15</td><td>15</td><td>19</td><td>9</td><td>8</td></tr>
<tr><td>Sample</td><td colspan="5">Carcass (7 primal cuts)</td></tr>
</table>

Sample preparation for carcass composition

Commercial slaughtering and dressing procedures were followed. On the day following slaughter, the chilled carcasses were sectioned down the vertebral column by band saw and one side (**right** side) subdivided into the following seven primal (wholesale cuts): neck, shoulder and shank, breast, rib, loin, leg (Figure 2) (Casey, 1982). The kidneys were removed and weighed for each carcass. The cuts were dissected into meat (muscle and intermuscular fat), bone and subcutaneous fat (SCF) in order to determine the physical (carcass) composition of each cut as well as cumulatively for the whole carcass. This was also done to determine the distribution of the various tissue types (% meat, % bone and % subcutaneous fat) in the carcass. The total soft tissue (fat and muscle) of the deboned side was used for proximate analysis (chemical composition) to determine the percentage protein, moisture, ash and fat (AOAC, 2005).

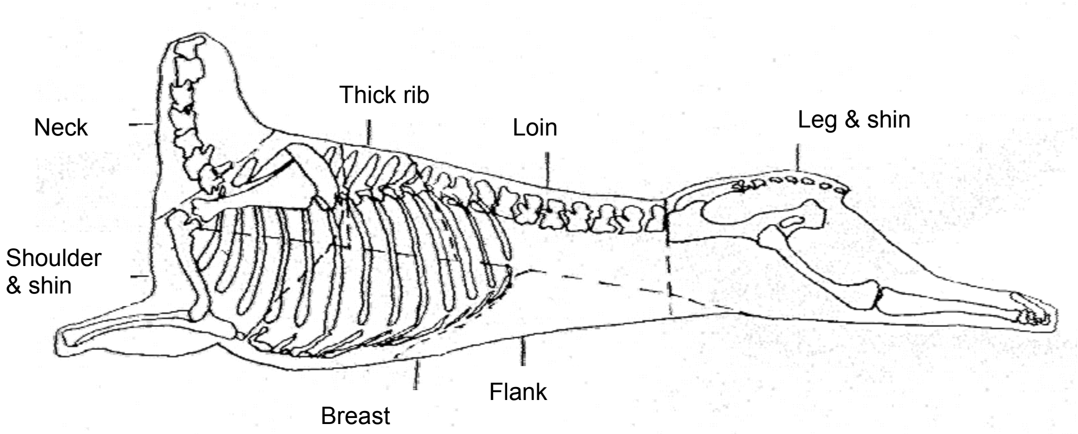


FIGURE 2: DISSECTION DIAGRAMME (CASEY, 1982:36)

Nutrient analysis

Sample for nutrient analysis

Three wholesale cuts (leg, loin, shoulder) of South African lamb (Dorper and Mutton Merino, from three regions) of an A-age group (0 incisors) with a fat code 2 (lean, ± 7 % SCF) were selected (Table 2). The meat and fat of each of the three wholesale cuts of one side (**right**) were analysed for raw nutrient content and three wholesale cuts of matching side (**left**) were analysed for cooked nutrient content (proximate, vitamins, minerals fatty acid and cholesterol).

TABLE 2: EXPERIMENTAL DESIGN FOR NUTRIENT ANALYSIS OF SOUTH AFRICAN LAMB (A2 CLASS)

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

Sample preparation for nutrient analysis

The same procedure as for carcass composition was followed for the raw nutrient analysis namely: the lamb carcasses were sectioned down the vertebral column by band saw, chilled and subdivided into the following seven wholesale cuts: neck, shoulder with shank, breast (cranial and caudal), rib, loin, leg with shin). The **right** sides of all the carcasses were used to determine the proximate analysis (macronutrients analysed) on raw cuts.

Earlier work done by Kirton, Barton and Rae, (1962:383) has shown that the composition of either side of the carcass has a similar composition. To prepare the composite samples of 18 animals for proximate and nutrient analysis, the meat and fat, respectively, of all three repetitions for each raw cut, from the **right** sides, (n = 7 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 and separable fat were homogenized with an Ultra Turrax T25 homogenizer after mincing and put into aluminium trays covered with a vacuum bag prior to the meat from being freeze-dried and sent of to the ARC analytical laboratory at Irene for proximate analysis (macronutrients analysed).

All the analytical procedures (Table 3) for the nutrient content of the lamb samples were done on a double blind basis in the various laboratories that form part of the South African National Accreditation Services (SANAS).

TABLE 3: METHODS USED FOR THE NUTRIENT ANALYSES OF RAW AND COOKED LAMB

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

Proximate analysis

Total fat

For determination of total fat, the AOAC method 960.39 (2005) was used where the content of a 2 g 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 5 g 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 °C overnight. The remaining residue is inorganic matter (ash).

Protein

The analysis is based on the Dumas Combustion method, AOAC 992.15 (2005), which is approved, by the AOAC, AOCS, ASBC and the AACC. The sample is combusted at ± 1100 °C – 1350 °C 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 by using the following factors:

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

Fatty acid profile

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

Thiamin (Vit B_1) and riboflavin (Vit B_2) were determined according to HPLC technique with fluorescence detection (Fellman et al., 1992). All analyses 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 ALASA 7.2.3 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.

Three cuts, representing the most commonly consumed cuts (shoulder, loin and leg), from the **left** sides were used to determine the cooked nutrient composition. These cuts were vacuum packed and frozen for two months at - 20 °C until the cooking process commenced. The leg, loin and shoulder cuts from the **left** sides were cooked before they were dissected into meat (muscle, intramuscular fat), bone and subcutaneous fat (SCF) in order to determine the nutrient analysis (proximate, vitamins, minerals, fatty acids and cholesterol) in the cooked composite sample (**left** sides) of the carcass (meat and fat, respectively).

Sensory analysis: Meat Quality

Sample for sensory analysis

Bratzler (1971:344) mentioned that, because of the greater size and uniformity of the longissimus (dorsi and lumborum parts) of the loin section, it has been used most frequently for studies on meat tenderness and juiciness. Therefore the loin cuts (bone-in) containing the *M. longissimus lumborum* (M.LL) (the first lumbar vertebra to the last lumber vertebra) of one side (left) of 66 Dorper wethers from the A age from five fat classes were used (Table 4). To achieve the five fat classes the lambs were fed intensively to three different live weights (30, 36 and 42 kg).

TABLE 4: EXPERIMENTAL DESIGN FOR EVALUATION OF SENSORY ANALYSIS ON THE M. LONGISSIMUS LUMBORUM (LOIN) CUT OF SOUTH AFRICAN LAMB

<table>
<tr><td>Breed type</td><td colspan="6">Dorper</td></tr>
<tr><td>Number of animals in study</td><td colspan="6">66</td></tr>
<tr><td>Sex of animals</td><td colspan="6">Wethers</td></tr>
<tr><td>Starting weight (kg)</td><td colspan="6">23 - 26</td></tr>
<tr><td>Days on feed</td><td colspan="6">90 – 120 days (4 - 6 months)</td></tr>
<tr><td>Slaughter weight (kg)</td><td colspan="2">30</td><td colspan="2">36</td><td colspan="2">42</td></tr>
<tr><td>Number of animals in slaughter group</td><td colspan="2">20</td><td colspan="2">24</td><td colspan="2">20</td></tr>
<tr><td>Distribution of carcasses per fat class</td><td>1</td><td>2</td><td colspan="2">3</td><td>4</td><td>5</td></tr>
<tr><td></td><td>15</td><td>15</td><td colspan="2">19</td><td>9</td><td>8</td></tr>
<tr><td>Sample</td><td colspan="6">M. longissimus lumborum cut of the left sides</td></tr>
</table>

Sample preparation for sensory analysis

Loin cuts were prepared and evaluated according to the American Meat Science Association research guidelines (AMSA, 1995:7 - 8) on the cooking and sensory evaluation measurements of fresh meat. The cuts were thawed over a 24 hour period at 4 °C before cooking The samples were then prepared according to a standardized dry heat cooking method in identical Mielé ovens (Mielé ovens, model H217) at 160 °C to an internal endpoint temperature of 70 °C (45 minutes per kilogram). The dry heat cooking method entailed the oven roasting, of the meat uncovered ion a flat open pan, with a rack to keep the meat out of the drip. No water (liquid) was added during cooking. A hand-held digital probe (model Kane - May 1012) was used to record the internal temperatures at the geometric centre of the meat according to the American Meat Science Association (AMSA, 1995: 7 - 8). Cooking losses were measured as part of the standard procedure. A standing period of ten minutes at room temperature (centrally controlled at 22 °C), following cooking, was allowed for all the samples. Thereafter, the M.LL (loin) muscle was removed from the bone and halved (transverse) for sensory analysis and shear force measurements respectively. Ten cubed samples (10 mm x 10 mm x 10 mm cubes) were cut from the middle of the muscle and immediately wrapped individually in pre-coded (with 3 - digit random numbers) aluminium foil squares (9 cm x 9 cm). These samples, at an internal temperature of ± 60 °C, were served in a monadic sequential order (one at a time, consecutively) on pre-warmed plates to the trained sensory panel within 20 minutes from the time the cut was removed from the oven.

Shear force resistance measurement

The remaining (half) portion of the sensory samples containing the M.LL were cooled overnight (12 hours) to a point where the internal temperature stabilized at 4 °C. The samples were allowed to reach room temperature (centrally controlled at 22 °C) before being cored. Eight cylindrical samples with a diameter of 12.7 mm were removed parallel to the grain of the meat. One shear value from each core (perpendicular to the fibre direction) was obtained using an Instron Universal Testing Machine (Model 4301) (Instron, 1990) with a Warner-Bratzler shear device mounted on a Universal Instron apparatus. The reported value in kg force represents the average peak force measurement.

Sensory and taste panel procedures

The purpose of quantitative descriptive analysis is to determine how samples (products) differ in specific sensory characteristics. An external trained sensory panel consisting of ten members was used for sensory analysis at the Meat Industry Centre (MIC). Potential candidates were recruited to take part in the research project. After a personal interview with each panellist, to establish his or her interest, availability for the entire project and health, the candidates were screened by determining the threshold of each panellist for the four basic tastes viz. sweet, sour, bitter and salt. The panel members were then selected to participate based on their ability to taste and smell (acuity), as well as their ability to evaluate meat sample attributes, i.e. tenderness, toughness and juiciness.

During a four-day training session (two hours per day), panellists received representative samples of each of the different treatments (fat codes) of Dorper loin samples (one at a time) and were trained in order to increase their sensitivity and ability to discriminate between specific samples and the sensory attributes of each (product) sample. A clear definition of each attribute (lexicon) was developed to describe the specific product attribute to be evaluated (Table 5).

A score sheet, with an eight-point category rating scale was used. Each sensory category attribute was verbally labelled, e.g. with one (1) denoting the least intense condition (e.g. extremely bland aroma) and eight (8) denoting the most intense condition (e.g. extremely intense aroma) was constructed (Annexure 1) and used to evaluate the different samples (Meilgaard, Civille & Carr, 1991: 53-55). The following sensory quality characteristics were evaluated: aroma intensity, initial impression of juiciness, first bite tenderness, sustained impression of juiciness, muscle fibre and overall tenderness, amount of connective tissue (residue), overall flavour and off-flavour. In order to ensure that panellists were not influenced in any way, no information regarding the nature of the samples was provided. Six samples were analysed on a blind basis during two sessions per day (three samples per session).

TABLE 5: DESCRIPTIONS OF EACH ATTRIBUTE AS USED BY THE TRAINED SENSORY PANEL TO EVALUATE THE LAMB SAMPLES

Attributes	Instructions and Lexicon
Aroma Intensity	Take a few short sniffs as soon as you remove the foil. An aroma associated with cooked lamb that has an important influence and contribution to the flavour of the cooked lamb cut.
Initial impression of juiciness	It is the amount of fluid exuded on the cut surface when pressed between thumb and index finger.
Sustained juiciness	The impression of juiciness that is formed when chewing. It is either dry with no fluid or juicy with moisture.
First bite tenderness	The impression of tenderness of the meat that is formed during the first bite.
Muscle fibre and overall tenderness	Chew sample with a light chewing action. The impression of tenderness of the meat when biting into the meat and evaluating whether the meat breaks easily between the teeth (tender) or has become tough/difficult to bite through.
Amount of connective tissue (residue)	Chew sample with a light chewing action. This is the chewiness of the meat.
Overall flavour	This is a combination of taste while chewing and swallowing the sample.
Off-flavour	Flavour not associated with lamb.

Two evaluation sessions per day, with three samples served in every session, over 11 days were conducted. During a tasting session, three - 3-digit coded samples representing the different treatments were served randomly (one at a time) to the individual panellists. In order to ensure that the panel members did not suffer from sensory fatigue, a short break of 20 minutes was introduced between the two tasting sessions per day. The ten panellists were seated in individual sensory booths to ensure unbiased objectivity and consistent responses, without being influenced by external factors. The samples were evaluated under red light conditions to mask possible colour differences. The sensory analysis facility used, is constructed with all the elements necessary for an efficient sensory program and is constructed according to the American Society for Testing and Materials (ASTM, 1989:15) design guidelines for sensory facilities. The samples were presented on a preheated (100 °C) glass plate. Water at room temperature was provided to cleanse the palate between samples. At each session, the panellists were instructed to evaluate the samples for the different sensory attributes.

DATA COLLECTION

According to Mouton (1996:146), “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 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. Cooking data in the sensory laboratory was captured on a cooking form. 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 checked and coded on spreadsheets using Microsoft Excel (2000), before statistical analyses were done.

STATISTICAL ANALYSES

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). Fat class (five) was used as the main effect and tested at a significance level of 99 % ($p \leq 0.01$). 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: 234-35).

Nutrient composition

Nutrient data obtained from the analysis were entered on a spreadsheet using Microsoft Excel (2000). Data was statistically analysed by the ARC-Biometry Unit using GenStat for Windows (2003). The significance of all the variables measured for each sample was 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: 234-35). A correlation matrix was constructed to test for significant correlations between attributes.

Sensory analysis: Meat quality

The significance of all the sensory attributes measured for each fat class of the Dorper loin cut was tested by means of factorial analysis of variance (ANOVA), which tested the main effect of the sample and sensory attributes, as well as the sample-by-sensory attribute interactions at a 5 % level of significance ($p \leq 0.05$). 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: 234-35). 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 subcutaneous fat, meat 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 subcutaneous fat, meat and bone are presented in a bar graph for visual interpretation of results.

The nutrient analysis of South African A age class, fat class 2 is presented in Chapter 4. The results are discussed as raw and cooked lamb, 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.

In Chapter 5, the sensory analysis on the loin cut of A age lamb, fat class 1-5 are discussed in terms of meat quality attributes. The results of the analysis of variance (ANOVA) are presented in a table and then discussed. The Principal Component Analysis (PCA) with the sensory results are presented in a scatter plot and discussed.

Reliability

Reliability depends on consistency and this was followed by having the same abattoir and laboratory team working throughout the study. Accurate data recording was done by hand on data collection forms; captured on computer onto a spreadsheet and double-checked, before the statistical analyses were done. Nutrient analysis on raw and cooked lamb meat were conducted on a double blind basis in a SANAS accredited laboratory (ISO/IEC, no 17025:2005), according to standardized methods to ensure accuracy, precision, delectability, repeatability as well as reliability. The use of control samples forms part of the daily routine in these laboratories to assure the quality of results. Sufficient replications of each sample were also used to ensure statistically reliable data. A steering group of external specialists were appointed to assess all the phases of the project and therefore unnecessary errors were limited. This process identified inconsistencies in the quality of the data and indicated possible problem areas in time. Training of people (abattoir team) during the pilot study ensured that all the criteria were met for reliability (Greenfield & Southgate, 2003:76). 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

Validity refers to the extent to which an empirical measurement provides adequate data that relates to the accepted meanings of particular concepts (Babbie & Mouton, 2002:123). Care was taken to ensure that the concepts were neither too complex nor vague. On the operational level, all sampling was representative and handled with utmost accuracy. A proper sampling plan was followed with representative samples from each area and sufficient replications of each sample were used to ensure statistically reliable and valid data.

Furthermore all the nutrient analyses were determined by a SANAS (South African National Accreditation Service) accredited laboratory on a double blind basis. All the analytical procedures (Table 1) for the nutrient content of the lamb samples were done on a double blind basis in laboratories (ISO/IEC 17025:2005) that forms part of the South African National Accreditation Services (SANAS). Control samples form part of the daily routine in these laboratories to assure the quality of results. Furthermore, all methods used for the nutrient analysis of lamb were validated. Finally in order to have been able to do a proper interpretation of the results, data were compared to findings in similar studies (literature) to substantiate the arguments.

Outcome of the study

Various outcomes were envisaged for this research study:

- Firstly the data will be published in three scientific articles.
- Secondly, the nutrient data and information will be included in the Medical Research Council's food composition tables to be used primarily for the assessment and the planning of South African human nutrient intake. For example, this data will also be used in food assistance or food delivery in epidemiological and clinical research, in food monitoring for nutritional content and safety, nutritional status of populations and food manufacturing.
- Thirdly, the carcass composition and quality information should be put to use by the retailer to trim certain cuts to the acceptable fat proportion for the consumer. The knowledge will also inform the consumer and assist them to make informed decisions when purchasing meat.

- Booklets and informative articles will be published to communicate this information to the consumer.

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3

THE INFLUENCE OF FAT SCORE AND FAT TRIMMING ON PRIMAL CUT COMPOSITION OF SOUTH AFRICAN LAMB

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In this chapter the style and layout, as prescribed by the Journal in which the article will be published namely, South African Journal of Meat Science, has been followed.

Abstract

The objectives of this study were firstly to determine the physical composition of cuts of South African lamb carcasses with different fat scores, and secondly to identify certain cuts suitable for trimming. In South Africa, sheep carcasses are classified according to age and, subjectively, according to the fat cover. Certain local meat companies have already altered at least a part of their operations to boneless retail cuts that could include the fat trimming of cuts to obtain a leaner more attractive cut for the consumer. Trimming of carcasses with high fat scores could also be an option for these operations provided that the cost/profit ratio is favourable. For this study, 66 grain-fed Dorper lambs (males and females) were divided into three groups and slaughtered at 30, 36 and 42 kg. Chilled carcass sides were subdivided into seven wholesale cuts. The cuts were dissected into meat (muscle, intermuscular and intramuscular fat), bone and subcutaneous fat (SCF) in order to determine the physical composition per cut and for the whole carcass. The soft tissue of the carcass was analysed for % total fat, protein, ash and moisture.

The percentages total fat in the carcass increased with 15.5 % over the five fat classes (according to SCF), with the largest increment between fat class 1 and 2, reaching a plateau from fat classes 3 up to 5. The % SCF of the loin increased the most (26 % units) as the fat score increased from score 1 to 5, followed by the flank, shoulder and neck cuts. The % meat (lean) of the neck, thick rib and breast showed no significant change between fat score 1 to 5, although the % bone decreased significantly (> 6 % units). Meat and bone proportions decreased significantly with increase in fat

score for the loin, flank, leg and shoulder. Overall, the composition of the loin cut was most affected by changes in the fat score.

Trimming reduced the boneless SCF level of the loin, leg and shoulder by 12 %, 6 % and 9 % units, respectively, when trimmed from a fat score 5 down to a fat score 3. Further trimming to fat score 1, reduced the % SCF by 18 %, 8 % and 5 % units on a boneless level for the loin, leg and shoulder cuts respectively. The SCF of neck and thick rib could be reduced significantly between 4 and 5 % units from fat score 5 to fat score 3. The neck, thick rib, breast and flank could be trimmed significantly from a fat score 3 to a fat score 1 level by 5 units. The final decision on implementing trimming procedures would be determined by weighing the cost involved against the possible extra profit gained from increased sales.

Keywords: Carcass composition, lamb, fat class, yield

Introduction

In South Africa carcasses are classified by law according to age and fat class. (National Department of Agricultural Product Standards Act, ACT No. 119 of 1990, and its regulations). Age is described according to the number of permanent incisors with age class A = 0 teeth, AB = 1-2 tooth, B = 3-6 tooth and C = more than 6 tooth. Carcasses are grouped into seven fat classes by means of visual appraisal of subcutaneous fat (SCF) (fatness classes from 0 = no fat, to 6 = excessively over fat). This classification system assists the meat traders to describe their specific requirements in simple terms when purchasing carcasses and to utilize variety in the market with the goal of optimum consumer satisfaction (SAMIC, s.a.). It provides the basis for assisting consumers in their selection of meat cuts to contribute to health and eating satisfaction. It also helps to provide a price structure and to fix selling prices of meat (SAMIC, s.a.).

According to Carpenter (1966) and Sañudo *et al.* (2000) leanness is an important characteristic for the consumer when purchasing meat. A small amount of fat is desirable to sustain palatability, increase tenderness and decrease the risk of the meat drying out, but too much fat decreases the retail cut yield. According to a consumer survey (ACNielsen, 2001) South African consumers generally find sheep meat too fat. They rated sheep meat (lamb and mutton) fourth, in preference after poultry, fish and beef for four characteristics directly or indirectly related to fatness, viz. “good for health”, “good source of protein”, ”nutritious” and “rich source of iron and other minerals”. According to Hopkins (1988), consumer perception of over-fatness leads to a downward trend in sheep meat consumption, even in South Africa. Furthermore, Garrett *et al.* (1992) reported the lack of flexibility with the traditional way of presenting mutton carcasses in Australia and the USA to retailers and ultimately to the consumer, thereby contributing to lower consumption. However, lamb has always played an important role in the diet of South Africans where it is seen as a traditional food for special occasions (ACNielsen, 2001).

As the variety and availability of food products increased in the diets of consumers in Western Countries, so did the incidence of diet-related diseases. The amount of fat and its degree of saturation play an important role in the predisposition of humans to coronary heart disease, a disease that remains one of the major causes of death world wide (Girolami *et al.,* 2003). One in four South Africans is affected by coronary heart disease (Radder & le Roux, 2005). However, according to Radder & le Roux (2005), meat is a universally valued and sought-after source for human nutrition. Since the popularity of red meat among South Africans is not expected to decrease in the near future, it is important to encourage consumers to make the right choices when purchasing meat.

Garrett *et al.* (1992) suggested innovative methods where boneless fat-trimmed (even intermuscular seam fat) sub-primals are presented to retailers, was by to enable them to supply healthier, leaner retail cuts to the consumers. Hopkins *et al.* (1995) described the introduction of a “trim lamb” range of cuts where boneless, fat trimmed cuts and even muscle separation within primal cuts are performed under the Prime Lamb Program in Australia. These cuts comply with Australian National Heart Foundation guidelines, with a fat content on average of less than 10 %. South African lamb and mutton are generally sold without any trimming. However, even in lean carcasses, there is a variation in the SCF from lean (1.7 % SCF) to excess fat (± 7 % SCF). This variation in fatness level may contribute to the fact that South African consumers reject sheep meat as being too fat (ACNielson, 2001).

The past decade has been characterised by rapid changes in consumer trends (Dransfield, 2001) and meat operations have to respond to these changing trends in a competitive market. In South Africa, certain meat companies [Just Lamb (www.justlamb.co.za) and natLAM (www.lawmeat.co.za)] have altered at least part of their operations to produce boneless retail cuts, even though fatness is mostly controlled by restriction of carcass fatness during production. Adjusting these operations to trim excess fat will not only result in a more acceptable product, but will also enable processors to use carcasses of various fat classes, thereby increasing the supply. However, as trimming is costly and could potentially add to the present high cost of sheep meat, it is necessary to have an estimate of the fat yield of different cuts to make this an economical proposition (Hopkins, 1988). In addition, as different cuts accumulate fat at different rates, information on fat accumulation of cuts over different fat classes (fat levels) needs to be known, to select those cuts and carcasses that can be processed cost-effectively.

In this study, the composition of seven retail cuts with regard to subcutaneous fat, meat (including intermuscular fat) and bone of lamb carcasses of five different fat classes were compared. It was accepted that normal trimming does not necessarily involve total removal of SCF and could also include removal of seam fat, although the latter process will need separation of individual muscles and this is not common practice in South Africa for sheep meat.

Experimental design

Materials and methods - Trial lay-out

Sixty six Dorpers lambs (rams and ewes,) with a starting weight between 23 - 26 kg and were divided into three groups with equal mean total group weights (Table 1). The three groups of animals were randomly allocated to three slaughter groups viz. 30, 36 and 42 kg. The animals were grain-fed in individual pens (1.5 m x 1 m) and slaughtered when the target weight in its slaughter group was reached. Commercial slaughtering and dressing procedures were followed.

Table 1: Experimental design for evaluation of carcass and chemical composition of South African lamb

Breed type	Dorper				
Number of animals in study	66				
Starting weight (kg)	23 - 26				
Days on feed	90 – 120 days (4 - 6 months)				
Slaughter weight (kg)	30		36		42
Number of animals in slaughter group	20		24		20
Distribution of carcasses per fat class	1	2	3	4	5
	15	15	19	9	8

Carcass processing

On the day following slaughter, the chilled carcasses were sectioned down the vertebral column by band saw and the **right** sides subdivided into the following seven primal (wholesale) cuts: neck, shoulder with associated shin, breast, rib, loin, leg and shin as well as flank (Figure 1). The kidneys were removed, weighed and noted for each carcass. Each cut was dissected into meat (muscle, intermuscular and intramuscular fat), bone and subcutaneous fat in order to determine the physical composition thereof as well as that of the whole carcass. This was also done to determine the distribution of the various tissues (% muscle, % bone and % fat) in the carcass.

The total soft tissue (fat and muscle) of the deboned side was used for proximate analysis (chemical composition) to determine the percentage protein, moisture, ash and fat (AOAC, 2005). The meat and fat from the 7 cuts of a single carcass 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 and separable fat were homogenized with an Ultra Turrax T25 homogenizer after mincing and put into aluminium trays covered with 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 lamb samples were done on a double blind basis in laboratories that form part of the South African National Accreditation Services (SANAS). Subcutaneous fat, meat and bone were expressed as a percentage of the carcass side's weight (without the kidney fat) and of the relevant cut. Proximate analysis (fat, protein, ash and moisture) was expressed as a proportion of the total amount of soft tissue (boneless) of the carcass side. The composition of each cut was also presented as subcutaneous fat and meat proportional to the weight of the edible tissue (boneless) of the cut.

Statistical analyses

Data was statistically analysed using the GenStat for Windows (2000) statistical computer program. The significance of the variables measured for each sample was tested by means of a one - way analysis of variance (ANOVA) (unbalanced block design). Fat class (unbalanced, class 1 (n=15), 2 (n=15), 3 (n=19), 4 (n=9) and 5 (n=8), excluding fat class 0 and 6) was used as the main effect and tested at a significance level of 99 % ($p \leq 0.01$). 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)

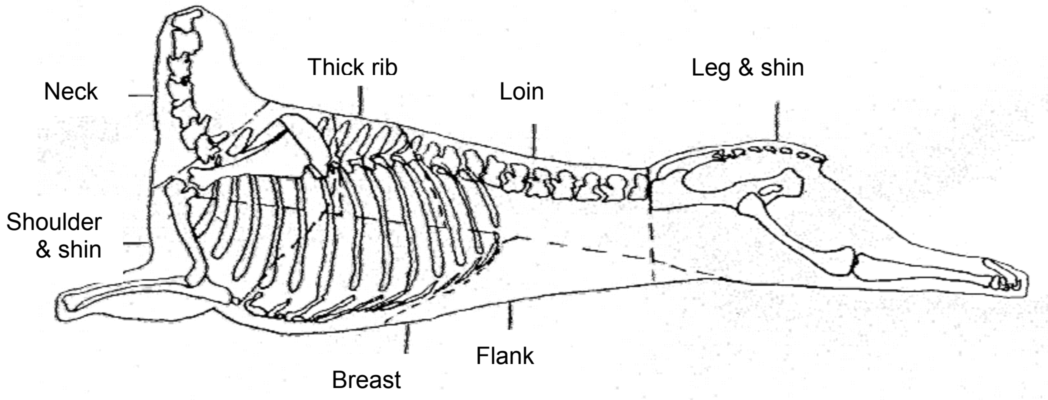

Figure 1 Dissection diagramme (Casey, 1982)

.According to the fatness classification of sheep, (National Department of Agriculture, 1990:9-14, in SAMIC s.a), the seven fat classes are described as follows:

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 A age class and fat class one to five of seven. No animals from the zero and six fat class were included.

Results

It is well known that muscle to bone ratio increases during initial growth (increase in weight of the animal). During the fattening period of growth, fatty tissue grows at a greater rate followed by muscle (meat) and then bone, so that the proportions of both tissues decrease in a regular manner as fat increases (Callow, 1948 and Berg & Butterfield, 1978).

Carcass weights (Table 2) ranged between 11.4 and 21.9 kg, and increased with an increase in fat class, but tended to taper off over fat class 3, 4 and 5. Carcasses from fat class 2 were significantly $p < 0.001$ heavier than those from fat class 1, and fat classes 3 to 5 were heavier than fat classes 1 and 2 ($p < 0.001$), but did not differ significantly ($p < 0.001$) from each other.

The percentage total fat in the soft tissue of the carcass increased with 15.5 % units (28.45-12.93) over the five fat classes with a concomitant decrease in percentage moisture (11.8 % units), ash (0.2 % units) and protein (2.6 % units), which agrees with the earlier findings of Callow (1948); Kemp *et al.* (1970, 1976) and Solomon *et al.* (1980). The % subcutaneous fat (% SCF) increased significantly by 13.0 % units over the five fat classes, with a decrease in the total % meat (6.1 % units) and bone (6.9 % units) between fat class 1 and 5. The largest variation between the classes in the present study both increases and decreases) was between fat class 1 and 2 for fat, protein and moisture, which is typical for the onset of the carcass fattening phase (Berg & Butterfield, 1978).

Table 2 Means (± SEM) for physical and chemical composition of the carcass per fat class (n=66)

Attribute	Unit	p-value	Fat Class				
			1 n = 15	**2** n = 15	**3** n = 19	**4** n = 9	**5** n = 8
Slaughter weight	kg	< 0.001	25.80^{a} ±1.29	34.63^{b} ±1.25	39.32^{b} ±1.11	39.86^{b} ±1.61	40.33^{b} ±1.71
Carcass weight (cold)	kg	< 0.001	11.40^{a} ±0.654	16.16^{b} ±0.632	19.09^{c} ±0.562	20.62^{c} ±0.816	21.89^{c} ±0.866
Fat thickness	mm	< 0.001	0.650 ±0.426	2.193 ±0.411	4.353 ±0.365	5.178 ±0.531	7.550 ±0.563
Chemical composition of soft tissue							
Total fat	%	< 0.001	12.93^{a} ±0.849	19.27^{b} ±0.820	22.98^{cd} ±0.729	26.11^{de} ±1.059	28.45^{e} ±1.123
Moisture	%	< 0.001	67.85^{d} ±0.66	62.91^{c} ±0.639	60.24^{bc} ±0.568	57.91^{ab} ±0.825	56.01^{a} ±0.875
Ash	%	< 0.001	1.00^{c} ±0.018	0.90^{b} ±0.017	0.83^{ab} ±0.015	0.80^{a} ±0.022	0.79^{a} ±0.023
Protein	%	< 0.001	18.40^{b} ±0.315	16.62^{a} ±0.304	15.91^{a} ±0.271	15.38^{a} ±0.393	15.76^{a} ±0.417
Carcass composition (% of carcass weight less the kidney plus fat)							
Subcutaneous fat	%	< 0.001	3.04^{a} ±0.243	7.45^{b} ±0.235	10.27^{c} ±0.209	13.21^{d} ±0.303	16.03^{e} ±0.321
Meat (lean)	%	< 0.001	77.12^{a} ±0.339	76.58^{a} ±0.327	74.63^{b} ±0.291	73.02^{b} ±0.422	71.05^{b} ±0.448
Bone	%	< 0.001	19.83^{d} ±0.394	15.97^{c} ±0.380	15.10^{bc} ±0.338	13.79^{ab} ±0.491	12.94^{a} ±0.521
Total meat (SCF + lean)	%	< 0.001	80.18^{a} ±0.394	84.02^{b} ±0.381	84.90^{b} ±0.338	86.21^{bc} ±0.492	87.06^{c} ±0.521
Kidney + fat	%	< 0.001	2.28^{a} ±0.261	3.30^{ab} ±0.252	3.75^{b} ±0.224	5.21^{c} ±0.325	5.18^{c} ±0.345

^{a,b,c,d,e} Row means with common superscripts, do not differ (p<0.001)
± Standard Error of Mean (SEM)
Meat = Muscle and intermuscular fat between muscle (IMF)

As animals grow older, weight increases until mature size is reached (growth phase) and the body composition and shape changes (developing phase). According to Hammond *et al*. (1971) as well as Berg & Butterfield (1978) the maximum relative growth ("growth curve") starts at the head and spreads down to the trunk. Secondly, growth curves start at the extremities of the limbs and move upwards. All these curves meet at the junction of the loin and last rib, this being the last region to develop. In this regard the growth gradient pattern of fat deposition is similar to that of muscle, according to the earlier report of Hammond (1932) and supported by later reports of Berg & Butterfield (1978) and Kempster *et al.* (1976b) i.e. growth gradients from the distal limbs converging in the abdominal/lumbar region.

In the present study, these patterns were confirmed where certain cuts were more influenced with regard to variation in tissue composition over fat classes than other cuts. These results are reported in Tables 3, 4 and 5 as well as visually presented in a bar graph (Figure 2) for comparison and interpretation. While Bruwer & Naudé (1987) reported on the total carcass composition for the different fat classes of the classification system, no data exist for the individual cut composition in South Africa and this is what was recorded in this present study.

Table 3 Means (± SEM) for the percentage subcutaneous fat for different lamb cuts of five fat classes (n=66)

Cut	p-value	Fat Class				
		1	2	3	4	5
Neck	< 0.001	3.48[a] ±0.610	7.73[b] ±0.589	8.31[b] ±0.524	10.87[bc] ±0.761	12.93[c] ±0.807
Shoulder with shin	< 0.001	2.03[a] ±0.531	3.69[a] ±0.513	5.98[b] ±0.455	9.49[c] ±0.662	13.26[d] ±0.702
Thick Rib	< 0.001	1.75[a] ±0.326	4.49[b] ±0.315	5.77[bc] ±0.279	6.98[c] ±0.406	9.29[d] ±0.431
Breast	< 0.001	4.97[a] ±0.523	7.08[ab] ±0.505	9.07[bc] ±0.449	11.64[cd] ±0.652	12.24[d] ±0.692
Leg with shin	< 0.001	2.91[a] ±0.419	6.99[b] ±0.404	9.90[c] ±0.359	13.03[d] ±0.522	14.94[d] ±0.554
Flank	< 0.001	6.50[a] ±0.943	13.46[b] ±0.911	18.20[c] ±0.809	19.74[c] ±1.176	19.50[c] ±1.247
Loin	< 0.001	1.84[a] ±0.907	12.58[b] ±0.876	17.85[c] ±0.779	21.70[c] ±1.131	28.98[d] ±1.200

a,b,c,d,e Row means with common superscripts, do not differ (p<0.001)
± Standard Error of Mean (SEM)

The percentage SCF increased significantly ($p<0.001$) in all seven cuts as fat class (Table 3) increased. In certain cuts, SCF was deposited in higher increments over fat classes than in others, especially between fat class 1 and 2, e.g. neck, thick rib, leg and flank and loin, where, in some cases, the fat content was more than double. In the last two fat classes (fat class 4 and 5) the fat increase was less especially for the neck, leg, breast and flank cuts. According to Kempster (1980/81) relative growth of subcutaneous fat in the loin, breast and neck 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 (1980-81) did not report on the flank.

Percentage lean (meat) decreased significantly between fat class 1 and 5 in the shoulder with shin, leg with shin, flank and loin but not for the neck, thick rib and breast cuts (Table 4). The proportional yield of bone decreased significantly between fat class 1 and 5 for all the cuts with an increase in fat class (Table 5), and this was expected, as bone is an earlier-developing tissue than muscle and fat (Berg & Butterfield, 1978). In cuts such as the neck, thick rib and breast where the lean (meat) yield did not vary significantly over the five fat classes, the increase in fat was inversely related to the decrease in bone. For the remaining cuts (shoulder, leg, flank and loin), both the % bone and lean (meat) decreased as the proportion of SCF increased across the fat classes. Diaz *et al*. (2005) reported that in suckling lambs, the lean (meat) yield of the leg were unaffected by weight or fat gain, while the bone decreased as fat proportions increased.

In general, the proportional lean (meat) yield decreased within each cut as fat score increased (Table 4). Of all the cuts, the loin decreased the most in yield over the fat classes with as much as 18 % units. In contrast, the proportional lean (meat) yield of the neck, thick rib and breast were the least affected by an increase in fat class.

Table 4 Means (± SEM.) for the percentage lean (meat) for different lamb cuts of five fat classes (n=66)

Cut	p-value	Fat Class				
		1	2	3	4	5
Neck	0.252	78.37 ±0.866	78.03 ±0.837	79.06 ±0.743	76.67 ±1.080	76.46 ±1.146
Shoulder with shin	< 0.001	73.63^{ab} ±0.543	75.40^{a} ±0.524	73.68^{ab} ±0.466	71.14^{bc} ±0.677	68.19^{c} ±0.718
Thick Rib	0.187	74.38 ±0.683	76.26 ±0.660	76.47 ±0.586	76.22 ±0.852	75.55 ±0.904
Breast	0.271	73.66 ±0.607	75.00 ±0.586	73.84 ±0.521	72.95 ±0.757	74.19 ±0.803
Leg with shin	< 0.001	77.67^{a} ±0.524	76.47^{ab} ±0.506	74.68^{bc} ±0.450	72.63^{cd} ±0.654	71.31^{d} ±0.693
Flank	< 0.001	90.90^{a} ±0.963	84.82^{b} ±0.930	80.22^{c} ±0.826	78.85^{c} ±1.201	79.24^{c} ±1.273
Loin	< 0.001	78.00^{a} ±0.915	74.18^{a} ±0.884	68.10^{b} ±0.786	67.60^{b} ±1.141	59.77^{c} ±1.211

^{a,b,c,d,e} Row means with common superscripts, do not differ (p<0.001)
± Standard Error of Mean (SEM)

Table 5 Means (± SEM) for the percentage bone in lamb cuts for five fat classes (n=66)

Cut	p-value	Fat Class				
		1	2	3	4	5
Neck	< 0.001	18.15^{a} ±0.581	14.25^{b} ±0.561	12.63^{b} ±0.499	12.46^{bc} ±0.725	10.61^{c} ±0.769
Shoulder with shin	< 0.001	24.34^{a} ±0.464	20.92^{b} ±0.448	20.34^{b} ±0.398	19.37^{b} ±0.578	18.55^{b} ±0.613
Thick Rib	< 0.001	23.87^{a} ±0.655	19.25^{b} ±0.632	17.77^{bc} ±0.562	16.81^{bc} ±0.816	15.17^{c} ±0.866
Breast	< 0.001	21.37^{a} ±0.502	17.92^{b} ±0.485	17.09^{b} ±0.431	15.40^{bc} ±0.626	13.57^{c} ±0.664
Leg with shin	< 0.001	19.42^{a} ±0.420	16.54^{b} ±0.046	15.43^{bc} ±0.361	14.35^{bc} ±0.524	13.76^{c} ±0.556
Flank	0.032	2.60 ±0.294	1.72 ±0.284	1.58 ±0.253	1.41 ±0.367	1.25 ±0.389
Loin	< 0.001	20.16^{a} ±0.852	13.25^{b} ±0.823	13.95^{b} ±0.731	10.70^{b} ±1.063	11.26^{b} ±1.127

^{a,b,c,d,e}Row means with common superscripts, do not differ (p<0.001)
± Standard Error of Mean (SEM)

Discussion

Sañudo *et al*. (2000) reported that too much fat on meat discourages the consumer and is often removed either before cooking or during the meal, especially by young people. Garrett *et al*. (1992) and Hopkins (1988) demonstrated the advantage of trimming and deboning certain cuts of the lamb carcass before retail sales, in order to present more acceptable and attractive cuts to the consumer and to have a larger supply basis (over fat carcasses) of lamb cuts suitable for the consumer. Carpenter (1966) stated that little information is available regarding the minimum fat covering needed on a lamb carcass in order to assure the desired product (cut) and that a fat covering of at least 5 mm is needed to prevent product dehydration and to produce an attractive retail cut. Five millimetres is equal to the fat class 3 score in the SA classification system but preferences will vary between consumer groups. Furthermore, the value is a mean value mostly measured on the loin, and other cuts may have more or less fat cover and also differ in their appeal to consumers.

The results of the present trial show that within a fat class (read vertically in tables 2-4) the different cuts contain different levels of SCF and that among the fat levels, the rates of SCF deposition differ between the cuts. Considering the major cuts most likely to be trimmed, viz. the shoulder with shin, leg with shin and loin, trimming from a fat score 5 to a fat score 3, will reduce the boneless SCF level by 9 % units for the shoulder, almost 6 % units for the leg and 12 % units for the loin. Further trimming to fat score 1, will reduce the % SCF with a further 5 %, 8 % and 18 % units on a boneless level for these three cuts. Due to the variation among cuts in the amount of fat deposition over fat scores, trimming certain cuts of fat score 5 carcasses down to fat score 3 will not have a significant impact on the SCF level, e.g. the breast and flank (Table 6). Apart from the shoulder, leg and loin discussed earlier, the SCF level of the neck and thick rib cuts could be reduced significantly between 4 and 5 % units from fat score 5 to fat score 3. All five these cuts could be trimmed significantly from a fat score 3 to a fat score 1 by at least 5 units (the flank = 12 % units).

Although Garrett *et al*. (1992) emphasized that seaming of the muscles i.e. separating the muscles, and removing all excess fat was necessary to obtain an acceptable final fat level in the cuts, they worked with USDA yield grades 2, 3 and 4, representing fat thickness levels in excess (9 mm, 14 and 20 mm, respectively) of the SA system (Zero to > 11 mm) and the carcasses of the present trial. Furthermore, Hopkins (1988) stated that the seaming of muscles required heavy lean carcasses (22-25 kg) to make it an economical and aesthetic proposition and these carcasses are not common in the local industry (Australia). Hopkins (1988) worked with bone-in cuts that were trimmed of excess SCF and the intermuscular fat (seam fat) left intact and concluded that trimming of SCF alone could remove most of the differences in composition of lamb cuts from carcasses of different fatness. He did, however, admit that the amount of untrimmed fat (mostly seam fat), increased with increase in fat score. Regarding the practical implication of separating muscles, Garret *et al*. (1992), pointed out that certain cuts like the shoulder and rack (loin) poses a problem to remove the seam fat as this fat depot makes up the larger portion of fat in these cuts and is therefore not an aesthetic or economical proposition.

Although intramuscular fat was not determined in the present study, the work of Kempster *et al.* (1957) could shed some light on the effect of SCF trimming on remaining fat in fat carcasses, such as the fat class 3 carcasses in the present trail. They reported that IMF and SCF increased at a higher rate in the loin than in the shoulder and at a higher rate in the shoulder than in the leg and chump. For the loin the rate of fat growth was higher than for the whole carcass, (1.3); for the shoulder slightly less (0.9) and for the leg less (0.7 – 0.9) than for the carcass. In addition, the rates of both depots were the same for the loin and shoulder but the growth coefficient for IMF of the shoulder was less than the SCF of the shoulder.

Extrapolating from these results in the present study the high increase of SCF in the loin over increasing fat classes would have been paralleled by similar increases in IMF. As a result trimming of fat class may produce loins with less fat cover (SCF) but still a relatively high total fat content due to IMF. As the rate of fat gain in the shoulder is less than in the loin (and whole carcass), but similar for SCF and IMF, the same applies as for the loin. In addition, as pointed out by Garret *et al*. (1992), the IMF makes out a large portion of the total fat of this cut. Therefore trimming of most of the SCF will still leave a large portion of IMF intact. Trimming of the SCF of the leg of fat carcasses has a slightly higher advantage due to the slower increase of IMF compared to SCF in this case, as total fat increases.

Table 6 Means (± SEM) for the percentage subcutaneous fat for the edible portion (boneless) of different lambs cuts and fat classes (n=66)

Cut	p-value	Fat Class				
		1	2	3	4	5
Carcass	< 0.001	3.80[a] ±0.270	8.86[b] ±0.261	12.08[c] ±0.232	15.32[d] ±0.337	18.39[e] ±0.358
Neck	< 0.001	4.25[a] ±0.707	9.04[b] ±0.683	9.52[b] ±0.607	12.45[c] ±0.881	14.43[c] ±0.935
Shoulder with shin	< 0.001	2.66[a] ±0.652	4.64[b] ±0.630	7.47[c] ±0.560	11.77[d] ±0.814	16.28[e] ±0.863
Thick Rib	< 0.001	2.29[a] ±0.394	5.55[b] ±0.380	7.01[b] ±0.338	8.39[b] ±0.491	10.94[c] ±0.521
Breast	< 0.001	6.31[a] ±0.615	8.63[a] ±0.594	10.92[b] ±0.528	13.76[b] ±0.767	14.16[b] ±0.813
Leg with shin	< 0.001	3.62[a] ±0.482	8.37[b] ±0.466	11.69[c] ±0.414	15.20[d] ±0.601	17.32[d] ±0.638
Flank	< 0.001	6.66[a] ±0.959	13.70[b] ±0.926	18.50[c] ±0.823	20.02[c] ±1.20	19.76[c] ±1.168
Loin	< 0.001	2.21[a] ±1.000	14.44[b] ±0.966	20.69[c] ±0.859	24.30[c] ±1.247	32.64[d] ±1.323

[a,b,c,d,e] Row means with common superscripts, do not differ (p<0.001)
± Standard Error of Mean (SEM)

As discussed earlier, trimming cuts to fat score 1 may not be appealing to all consumers or be optimal for cooking according to Carpenter (1966), but will have different effects on different cuts with regard to the final amount of fat removed. Depending on the consumer it may enable the process to supply cuts from broader supply basis.

Although the option of trimming as discussed above, refers to both over fat carcasses in general and over fat cuts within the same (lower) fat score, finally, the costs involved need to be weighed against the possible extra profit. In general, it is more expensive to gain fat compared to muscle. On the other hand over fat carcasses obtain lower prices. Therefore, the reason for trimming over fat carcasses will be to gain from lower prices of normally limited numbers of these carcasses in order to increase available product. Furthermore, the cost of trimming (labour and value of trimmed fat) should be measured against the lower value of the carcass (Bruwer *et al*., 1987) and the higher price (compared to the carcass) the consumer is willing to pay for the trimmed product. Hopkins *et al*. (1995) and Hopkins (1988) showed that both weight and fatness of the carcass influenced the processing time (cost). According to Hopkins *et al*. (1995), consumers responded positively to “Trim Lamb” an Australian Meat and Livestock promotion. This response within the South African context will probably depend on the quality of the final product in terms of final fat content and consumers in general. Refer to Figure 2 for a summery of cut composition data presented in this study.

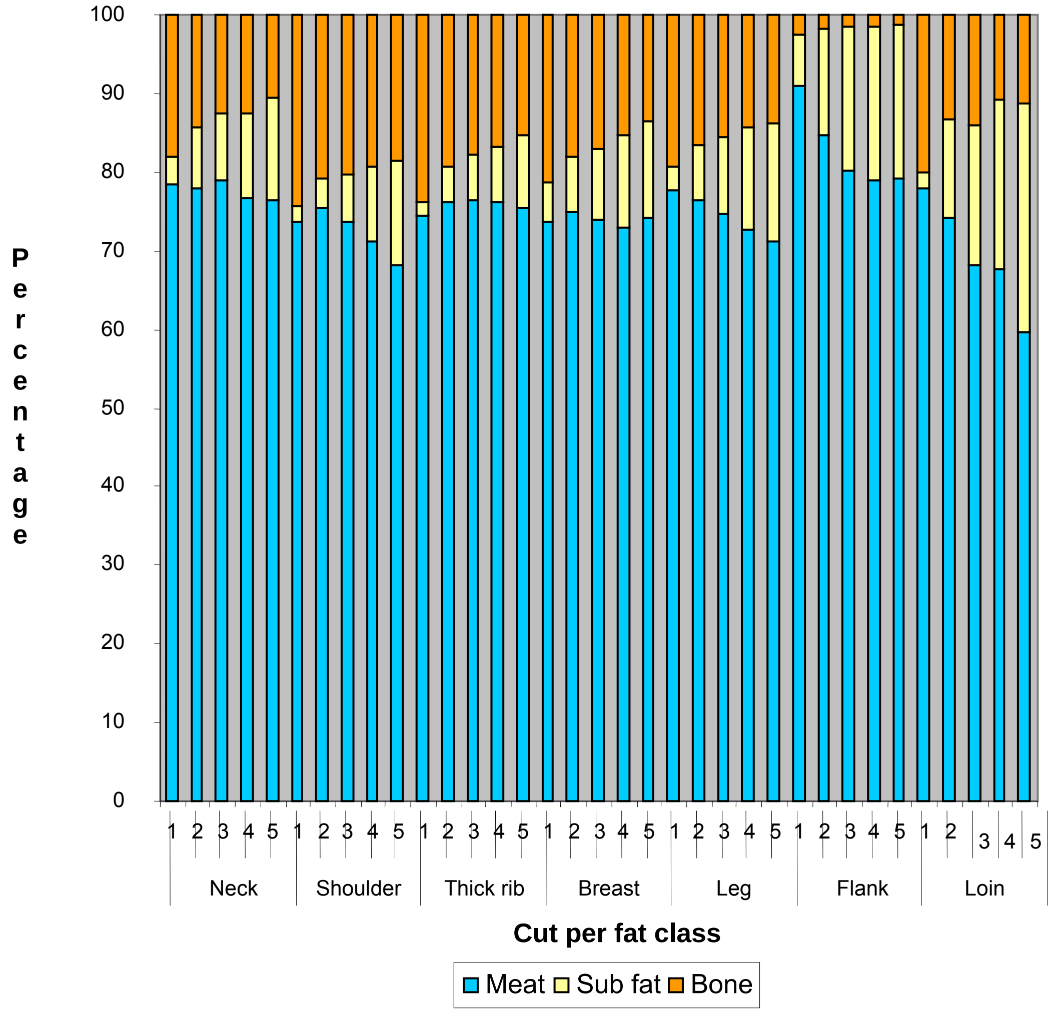

Figure 2 Percentage meat, fat and bone per fat class for each cut

Using the data of Table 2 and Table 3, a robust calculation of cost of trimming could be made using the average cost of trimming could be made by using the average core weights of 19 and 22 kg for fat class 3 and 5, respectively and the difference in subcutaneous fat % between fat class 3 and 5. It was calculated that about 1 kg of fat is trimmed off the class 5 carcasses. It was assumed that the fat class 3 carcasses is not trimmed and that processing time of fat carcasses double the processing time of a fat carcass as was reported by Hopkins (1989). If a conservative labour cost of R 5 / hour was used, the extra processing time (10 min vs. 20 min) and the trim loss of 1 kg resolved in a cost different of R 2 / kg. In other words fat carcasses need to be purchased at R 2 / kg less to be trimmed to medium fatness (fat code 3) while also considering that the final product is not exactly the same in terms of tissue composition and may therefore achieve a lower selling price.

Conclusions

With increasing consumer demand for lean meat, the relationship between fatness and eating quality as well as healthy lean meat portions has become the focus point for the meat industry lately. The cutting data in this study provides retailers with an insight into the variation in SCF of the different cuts of the carcass at different fat levels (fat scores). If the data is combined with efficient trimming skills of innovative retail operations, carcasses over a broad spectrum of fat levels could be processed into higher-value cuts that are more acceptable and attractive to fat consumers sensitive to dietary fat. In some instances, depending on the price of the carcass and the cost of trimming (labour and value of trimmed fat), further processing of over fat carcasses, can provide more affordable cuts to the consumer. On the other hand a certain sector of the consumer corps may be willing to pay premium prices if the final product is perceived as being healthier and this could perhaps justify the trimming of any cut to consumer standards. No information was gained on the intermuscular fat and previous work has showed that excessive fat may still remain in certain cuts of over fat carcasses trimmed of SCF. Therefore, further investigation into the remaining excessive fat of different cuts at different fat levels after trimming could be valuable, when decisions on trimming for specific markets are made. Consumer perceptions on the trimmed product vs. the price should also be investigated.

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4

THE NUTRIENT COMPOSITION OF SOUTH AFRICAN LAMB (A2 CLASS)

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"Knowledge of the chemical composition of foods is the first essential in dietary treatment of disease or in any quantitative study of human nutrition"

– McCance and Widdowson, 1940

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

ABSTRACT

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

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

INTRODUCTION

As in many other countries, South Africa is actively involved in analysing foods for the compilation of food composition data. Currently, only 41 % of all South African food values in the Medical Research Council's tables are derived from South African foodstuffs (SAFCoD, 2000). The current data on mutton (lamb and sheep) that appear in the MRC's food composition tables of 1999 are derived from the United States Department of Agriculture (USDA) database (Sayed, Frans & Schönfeldt, 1999:51, 65).

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

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

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

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

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

Table 1:

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

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

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

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

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

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

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

Food choices may have a direct impact on a person's health status. These choices are repeated over a long period (years or decades) and have major positive or negative health effects (Kruger, Van der Spuy & Viljoen, 2003:271). Therefore, in order to evaluate a person's food intake according to the Recommended Dietary Allowance (RDA) (Whitney & Rolfes, 2002:1), the nutritional composition of the diet is calculated by making use of food composition databases, either in computerized soft ware or printed form. This information provides the average nutrient content for a given amount of food, based on the chemical analysis of a number of food samples. Information on the nutrient content of a particular food can also be used as a standard reference to determine nutrients obtained from the foodstuff consumed throughout a country (Latham, 1997:251).

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

Certain segments of our population are consuming significant amounts of lamb, and yet there is a lack of comprehensive, South African nutrient composition data on lamb. Following the need for such data, as identified in 1987 by the South African Food Composition Data (SAFCoD), the Agricultural Research Council, Livestock Business Division, Irene, initiated a research focus area in 1988, to determine the nutrient content of South African animal products. Therefore, the aim of this research was to determine the nutrient composition of South African lamb, in order to incorporate the data into the Food Composition Tables of the Medical Research Council of South Africa.

MATERIALS AND METHODS

Sampling

The South African classification system (National Department of Agriculture, 1990:9-14) is designed to describe carcasses according to tissue composition and potential eating quality (tenderness). Carcasses are grouped into seven fat classes by means of visual appraisal (fatness class from 0 = no fat to 6 = excessively over fat). According to the fatness classification (National Department of Agriculture, 1990:9-14) an A age class, fat code 2 lamb will have at least 1 mm, but not more than 4 mm fat, and more than 5.6 % but not more than 8.5 % subcutaneous fat (SCF) (average of 7 % SCF).

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

Industry Centre of the then ARC-ANPI, Irene. Upon arrival, all the carcasses were weighed, covered with plastic wrap to prevent moisture loss and chilled at 4 °C overnight and dissected the following day. The lamb carcasses consisted of the skinned, eviscerated body from which the head, feet, kidney and kidney fat had been removed.

Carcasses were sectioned down the vertebral column with a band saw and then subdivided into the following primal cuts: neck, thick rib, flank, shoulder with shank, breast, loin, leg with shank. Three cuts (shoulder, leg and loin), representing the most commonly consumed cuts, taken from both sides, were used to determine the cooked (left side) and raw (right side) nutrient composition. The cuts, from the left sides used for the cooked analysis, were vacuum packed and frozen for two months at - 20 °C until the cooking process commenced. The raw and cooked nutrient data of the three cuts was compared based on the assumption, (Kirton, Barton and Rae, 1962:383-385) that the chemical composition of the two sides is similar or almost identical.

Table 2:

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

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

Sample preparation

In order to comply with the new Draft Regulations relating to the labelling and advertising of foodstuffs, as part of the Foodstuffs, Cosmetics and Disinfectants Act, Act 54 of 1972, (http://www.doh.gov.za/department/dir_foodcontr.html), it was decided that a composite of three carcasses would be used as a basis of the study. The use of composite samples for analysis rather than individual samples is justified through budgeting constraints and is an accepted approach in food composition studies (Greenfield and Southgate, 2003:50).

Right sides

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

Left sides

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

Preparation of the raw and cooked composite samples

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

Analyses

The analytical procedures (Table 3) for the nutrient content of the lamb samples were done on a double blind basis in the laboratories (ISO/IEC:17025:2005) that form part of the South African National Accreditation Services (SANAS). Reference samples form part of the daily routine in these laboratories to assure the quality of results. A proper sampling plan was followed with representative samples from each area and sufficient replications of each sample were used to ensure statistically reliable and valid data.

Table 3:
Methods used for the nutrient analyses of raw and cooked lamb

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

STATISTICAL ANALYSES

Data was statistically analysed by the ARC-Biometry Unit using GenStat for Windows (2003). The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (whole plots) and treatment (raw and cooked – sub-plots), as well as the cut-by-treatment interaction was tested at the 5 % level of significance ($p \leq 0.05$). If a main effect was significant, the Fisher's protected t-test with Least Significant Difference (LSD) was applied, to determine the direction of the differences between mean values (Snedecor, & Cochran, 1980: 234-35).

RESULTS AND DISCUSSION

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

Table 4:

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

NUTRIENTS ANALYSED	Unit	p-value	SEM	RAW (n=6)	COOKED (n=6)
PROXIMATE ANALYSIS:					
Moisture	g	<0.001	0.395	71.5	65.4
Protein (Nx6.25)	g	<0.001	0.406	18.3	25.1
Fat	g	0.217	0.306	9.01	8.44
Ash	g	<0.001	0.287	2.88	1.07
Food energy (calculated)	kJ	<0.001	14.4	644	745
MINERALS:					
Magnesium (Mg)	mg	0.405	1.261	20.1	21.7
Potassium (K)	mg	0.852	62.6	291	298
Sodium (Na)	mg	0.302	7.90	83.4	71.3
Zinc (Zn)	mg	0.196	0.275	2.25	1.72
Iron (Fe)	mg	0.260	0.198	0.96	0.63
VITAMINS:					
Thiamin (B_1)	mg	0.017	0.015	0.10	0.04
Riboflavin (B_2)	mg	0.102	0.013	0.09	0.05
Niacin (B_3)	mg	0.869	0.248	1.47	1.42
Pyridoxine (B_6)	mg	0.003	0.054	0.40	0.12
Cyanocobalamin (B_{12}))	µg	0.003	0.493	3.54	0.93
LIPIDS: **Saturated fatty acids (SFA)**					
14:0	g	0.297	0.038	0.57	0.50
16:0	g	0.111	0.086	2.22	1.99
18:0	g	0.002	0.048	1.46	1.07
20:0	g	0.137	0.002	0.02	0.02
Monounsaturated fatty acids(MUFA)					
16:1	g	0.983	0.009	0.19	0.19
18:1n9t	g	0.009	0.017	0.31	0.21
18:1n9c	g	0.001	0.050	3.12	2.65
Polyunsaturated fatty acids (PUFA)					
18:2n6t	g	0.215	0.003	0.02	0.02
18:2n6c	g	0.233	0.014	0.25	0.22
Cholesterol	mg	0.001	4.15	62.8	87.7

Raw and cooked data relates to the shoulder, loin and leg cuts only
p-value: F-probability to test for significant differences between composite samples (cuts)
SEM: Standard Error of Means. The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (n = 12 - whole plots) and treatment (n = 18 -raw and cooked carcass sides – sub-plots), as well as the cut-by-treatment interaction (n = 6 composite samples) was tested for the 5 % level of significance ($p \leq 0.05$).

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

Table 5:

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

NUTRIENTS ANALYSED		RAW CUTS (n = 12)					COOKED CUTS (n = 12)				
	Unit	p-value	SEM	Shoulder	Loin	Leg	p-value	SEM	Shoulder	Loin	Leg
PROXIMATE ANALYSIS:											
Moisture	g	0.012	0.741	70.8 [a]	70.1 [a]	73.7 [b]	<0.001	0.478	66.8 [b]	63.5 [a]	66.0 [b]
Protein (Nx6.25)	g	0.346	0.638	18.0	17.8	19.0	<0.001	0.541	23.1 [a]	27.8 [b]	24.5 [a]
Fat	g	0.003	0.814	9.63 [a]	11.3 [a]	6.15 [b]	0.018	0.515	9.86 [a]	7.80 [b]	7.67 [b]
Ash	g	0.918	0.711	2.93	2.65	3.06	<0.001	0.016	0.95 [a]	1.20 [c]	1.05 [b]
Food energy (calculated)	kJ	0.014	33.9	662[a]	718[a]	552 [b]	0.438	20.4	757	755	722
MINERALS:											
Magnesium (Mg)	mg	0.076	3.01	13.9	22.7	23.8	<0.001	0.674	17.7[a]	24.2[b]	22.9[b]
Potassium (K)	mg	0.134	51.7	201.	323	351	<0.001	7.51	261[a]	331[c]	303[b]
Sodium (Na)	mg	0.495	19.1	68.0	101	82	<0.001	1.528	68.9[b]	83.3[c]	61.9[a]
Zinc (Zn)	mg	0.512	0.474	1.99	2.05	2.71	0.208	0.357	1.24	2.20	1.71
Iron (Fe)	mg	0.397	0.197	0.75	0.99	1.14	0.227	0.439	-	0.62	1.20
VITAMINS:											
Thiamin (B_1)	mg	0.822	0.021	0.11	0.09	0.10	0.740	0.030	0.03	0.04	0.06
Riboflavin (B_2)	mg	0.954	0.027	0.09	0.08	0.09	0.535	0.018	0.04	0.07	0.05
Niacin (B_3)	mg	0.525	0.479	1.70	1.02	1.71	0.736	0.342	1.37	1.25	1.63
Pyridoxine (B_6)	mg	0.099	0.122	0.26	0.32	0.64	0.716	0.030	0.12	0.13	0.10
Cyanocobalamin (B_{12})	µg	0.803	1.085	4.02	3.61	3.00	0.697	0.188	0.8	0.2	1.1
LIPIDS:											
Saturated fatty acids (SFA)											
14:0	g	0.111	0.095	0.62	0.69	0.39	0.694	0.066	0.50	0.47	0.42
16:0	g	0.010	0.238	2.50 [a]	2.67 [a]	1.50 [b]	0.562	0.120	2.06	1.97	1.86
18:0	g	<0.001	0.132	1.64 [a]	1.86 [a]	0.88 [b]	0.329	0.101	1.10	1.08	1.30
20:0	g	0.120	0.006	0.03	0.03	0.01	0.045	0.005	0.02	0.01	0.02
Monounsaturated fatty acids (MUFA)											
16:1	g	0.152	0.028	0.21	0.21	0.14	0.113	0.009	0.20	0.18	0.16
18:1n9t	g	0.061	0.061	0.33	0.42	0.19	0.907	0.048	0.23	0.24	0.21
18:1n9c	g	<0.001	0.206	3.53 [a]	3.70 [a]	2.14 [b]	0.294	0.102	2.88	2.63	2.71
Polyunsaturated fatty acids (PUFA)											
18:2n6t	g	0.607	0.005	0.03	0.02	0.02	0.886	0.005	0.02	0.02	0.02
18:2n6c	g	0.018	0.029	0.28 [a]	0.29 [a]	0.17 [b]	0.891	0.034	0.24	0.22	0.24
Cholesterol	mg	0.966	6.09	64.0	61.8	62.7	0.732	6.23	85.0	86.3	91.7

- Value not available
p-value: F-probability to test for significant differences between composite samples
SEM: Standard Error of Means. The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (n = 12 – whole plots) and treatment (n = 18 raw and cooked – sub-plots), as well as the cut-by-treatment interaction (n = 6) was tested at the 5 % level of significance ($p \leq 0.05$). Means with different letters (a, b or c) are significant different.

Of the three raw cuts, the leg had significantly less fat when compared to the shoulder and the loin cuts which contained the highest fat value. A study done by Hoke, Buege, Ellefson and Maly, (1999:102, 108) observed the same trend in that an inverse relationship existed between moisture and fat content. In their study the highest fat and lowest moisture content was found to be in the raw lean rib and blade cuts. As a result of higher fat the loin had the highest energy value of the three cuts, followed by the shoulder cut and then the leg with the lowest energy value. In addition the same was found for the fatty acid profile, where the raw leg cut contained the lowest fatty acid content of the three cuts i.e. C16:0 (1.50 g / 100 g), C18:0 (0.88 g / 100 g) saturated fatty acids, C18:1n9c (2.14 g / 100 g) monounsaturated fatty acid and C18:2n6c (0.17 g / 100 g) polyunsaturated fatty acid. Maturity of animals influences the fatty acid composition of the meat. Ono *et al.* (1984:1237, 1239), studied lambs from two age groups and found that lambs from younger animals had higher amounts of some of the saturated fatty acids, and a higher polyunsaturated/saturated fatty acid ratio than those of older animals.

According to the results (Table 5), the only significant differences between the cooked cuts were for the moisture, protein, fat, energy as well as three minerals (magnesium, potassium and sodium). Moisture losses due to cooking resulted in an increase in the protein and cholesterol concentration. The shoulder and leg had significantly more moisture than the loin cut. According to Lawrie (1998:85, 259) it is feasible that significant differences may exist between specific muscle locations in the carcass or that breed and age has an effect. The essential amino acids may also differ at different parts of the animal (Lawrie, 1998:85, 259). The cooked loin cut (27.8 g / 100 g) had significantly ($p < 0.001$) more protein when compared to the leg (24.5 g / 100 g) and shoulder cuts (23.15 g / 100 g). As expected, the cooked shoulder had significantly more fat than the cooked loin and leg cuts. A significant difference was found for ash content, with the cooked loin cut having the highest ash content, followed by the cooked shoulder cut. Except for sodium, the cooked shoulder cut had the lowest mineral content of the three cooked cuts, and the loin cut had the highest mineral content except for iron. The shoulder contained significantly less magnesium when compared to the loin and the leg. The loin had significantly more potassium with the shoulder the least. The leg cut had significantly lower sodium content, when compared to the loin cut. The loin cut had the highest zinc content, although not significantly, when compared to the leg and the shoulder. These results contrasted the findings of the study by Ono *et al.* (1984:1239) where the blade chop (shoulder cut) showed the highest value for zinc and the loin chop the lowest. There were no significant differences in the nutrient values for the vitamins and fatty acids and cholesterol when comparing the three cooked cuts.

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

Table 6:

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

NUTRIENTS ANALYSED				RAW (n=6)			COOKED (n=6)		
	Unit	p-value	SEM	Shoulder	Loin	Leg	Shoulder	Loin	Leg
PROXIMATE ANALYSIS :									
Moisture	g	0.054	0.624	70.8	70.1	73.7	66.8	63.5	66.0
Protein (Nx6.25)	g	0.007	0.591	18.0 [a]	17.8 [a]	19.0 [a]	23.1 [b]	27.8 [c]	24.5 [b]
Fat	g	0.007	0.681	9.63[b]	11.25 [b]	6.15 [a]	9.86 [b]	7.80 [a]	7.67 [a]
Ash	g	0.824	0.503	2.93	2.65	3.06	0.95	1.19	1.05
Food energy (calculated)	kJ	0.059	28.0	662	718	552	757	755	723
MINERALS:									
Magnesium (Mg)	mg	0.545	2.182	13.9	22.7	23.8	18.0	24.2	22.9
Potassium (K)	mg	0.340	36.9	201	323	351	261	330	303
Sodium (Na)	mg	0.716	13.53	67.9	100.7	81.6	68.9	83.3	61.8
Zinc (Zn)	mg	0.470	0.419	1.99	2.05	2.71	1.24	2.20	1.71
Iron (Fe)	mg	0.564	0.340	0.75	0.99	1.14	-	0.62	1.20
VITAMINS:									
Thiamin (B_1)	mg	0.682	0.026	0.11	0.09	0.10	0.03	0.04	0.06
Riboflavin (B_2)	mg	0.700	0.023	0.09	0.08	0.09	0.04	0.07	0.05
Niacin (B_3)	mg	0.807	0.416	1.70	1.02	1.71	1.37	1.25	1.63
Pyridoxine (B_6)	mg	0.101	0.089	0.26	0.32	0.64	0.12	0.13	0.10
Cyanocobalamin (B_{12})	µg	0.768	0.779	4.02	3.61	3.00	0.83	0.91	1.05
LIPIDS:									
Saturated fatty acids (SFA)									
14:0	g	0.093	0.097	0.62	0.69	0.39	0.59	0.42	0.50
16:0	g	0.020	0.236	2.50 [b]	2.67 [b]	1.50 [a]	2.05 [a]	1.92 [a]	2.00 [a]
18:0	g	0.001	0.140	1.64 [b]	1.86 [b]	0.88 [a]	0.78 [a]	1.15 [a]	1.27 [b]
20:0	g	0.034	0.006	0.03 [a]	0.03 [a]	0.01 [b]	0.01 [b]	0.02 [b]	0.03 [a]
Monounsaturated fatty acids (MUFA)									
16:1	g	0.100	0.026	0.21	0.21	0.14	0.22	0.17	0.18
18:1n9t	g	0.076	0.057	0.33	0.42	0.19	0.22	0.01	0.18
18:1n9c	g	<0.001	0.200	3.53 [c]	3.70 [c]	2.14 [a]	2.60 [b]	2.63 [b]	2.70 [b]
Polyunsaturated fatty acids (PUFA)									
18:2n6t	g	0.567	0.005	0.03	0.02	0.02	0.02	0.02	0.02
18:2n6c	g	0.069	0.033	0.28	0.29	0.17	0.20	0.24	0.23
Cholesterol	mg	0.857	6.26	64	62	63	85	86	92

- Value not available
p-value: F-probability to test for significant differences between samples
SEM: Standard Error of Means. The significance of all the variables measured for each sample was tested with split-plot analysis of variance (ANOVA), whereby the main effect of the cuts (n = 12 - whole plots) and treatment (n = 18 raw and cooked – sub-plots), as well as the cut-by-treatment interaction (n = 6) was tested at the 5 % level of significance ($p \leq 0.05$). Means with different letters (a, b or c) are significant different

shoulder, loin and leg cuts when compared to the raw shoulder, loin and leg cuts. Furthermore, the cooked loin cut contained the most protein (27.79 g / 100 g edible portion) of the three cooked cuts.

The total fat content ranged from 6.15 g / 100 g in the raw leg and 11.25 g / 100 g in the raw shoulder to between 7.67 g / 100 g in the cooked leg and 9.86 g / 100 g in the cooked shoulder cut. According to Williamson, Foster, StanNer and Buttriss (2005:325), the more fat the meat contains, the higher the energy content.

In this study the iron content differed, although not significantly, between the three raw and cooked samples. Iron content decreased in the cooked loin cuts but showed an increase in the cooked leg cut (no value for cooed shoulder). The raw shoulder cut had 0.75 mg iron / 100 g. The same result was found for the raw loin (0.99 mg iron / 100 g) when compared to the cooked loin cut (0.62 mg iron / 100 g). However, the opposite was found for the cooked leg cut, where the raw leg contained 1.14 mg iron / 100 g iron compared to 1.20 mg / 100 g iron in the cooked cut. The increase of mineral content in cooked meat is mainly due to moisture loss (Lawrie 1998:260). Similar results were found by Lombardi-Boccia, Martinez-Dominguez and Aguzzi (2002:1740), where cooking of lamb cuts showed an increase in the iron content between raw and cooked samples. Furthermore, when iron values for raw lean lamb are compared with that of lean beef (11 % fat) (Schönfeldt, Visser, Van Niekerk & Van Heerden, 1996:18, 20), the raw loin lamb cuts had a higher iron content than beef loin, (0.99 mg / 100 g (lamb, loin) vs. 0.63 mg / 100 g (A age beef loin with 11 % fat). When cooked, the opposite was found, cooked beef loin, contained more iron (1.94 mg) per 100 g gram portion than cooked lamb loin (0.62 mg / 100 g edible portion) (Schönfeldt, Visser, Van Niekerk & Van Heerden, 1996:18, 20). This could be attributed to the fact that iron is bound in the haemoglobin in red meat and therefore, a concentration effect take place with the more protein present associated with a higher iron content. Kruger, Van der Spuy and Viljoen (2003:344) and Lombardi-Boccia, et al. (2005:39-46), emphasised that red meats are the richest source of highly available iron in the diet because it occurs in the most bio-available form, namely haem iron, which is only found in food from animal origin. According to Lawrie (1998:260) in respect to species differences the high content of iron in beef reflects the greater concentration of myoglobin in comparison to mutton or pork.

The cooked shoulder cut contained the least vitamin B_1, B_2 and B_{12} of the three cooked cuts: the cooked loin cut had the least vitamin B_3 and the cooked leg the least vitamin B_6. The vitamin content for the selected B vitamins of the three cooked lamb cuts were lower, although not significantly, than that of the raw cuts. The cooked shoulder cut, except for vitamin B_3 and B_6, contained the least vitamin B_1, B_2 and vitamin B_{12} (0.8 µg / 100 g), while the cooked loin cut contained the least vitamin B_3 (1.25 mg / 100 g) and the cooked leg cut, the least vitamin B_6 (0.10 mg / 100 g). This could be attributed to the fact that cooking influences the variability of water soluble vitamins in meat due to instability to heat or light and liquid (Lombardi-Boccia *et al.,* 2005:40). However, when compared to other meat products, it is clear that lamb is a good source of the B vitamins, especially vitamin B_{12}, as supported by Badiani, Nanni, Gatta, Bitossi, Tolomelli and Manfredini (1998:97).

Cooking of the three cuts had a concentrating effect on all the nutrients, due to the associated decrease in moisture content during cooking. The only exception was iron, an important nutrient in the diet, which decreased in the loin cut and exhibit increased iron content in the leg cut. These results are similar to those reported by Purchas, Rutherfurd, Pearce, Vather and Wilkinson (2004:206), where a large proportion of the haem iron in beef *Semitendinosus* muscle decreased during cooking.

The cooked shoulder and loin cuts (table 6) mainly contained less fatty acids than raw cuts while the cooked leg cut contained more of the C14:0, C16:0 and C20:0 saturated fatty acids than that of the raw cut. The cholesterol content for all three cooked lamb cuts was higher, although not significantly, than the raw cuts, with the shoulder cut containing the highest cholesterol. The cooked shoulder cut had the highest SFA (C14:0 – 0.59 g /100 g and C16:0 – 2.05 g / 100 g) content except for C18:0 that was the lowest (0.78 g 100 g) compared to the three samples. The cooked shoulder contained the highest C16:1 and C18:1n9t fatty acids with the least C18:1n9c MUFA as well as PUFA C18:2n6t and C18:2n6c. According to Lawrie (1998:85, 259) it is feasible that significant differences may exist between the nutrient content of specific muscle locations in the carcass. However, research in the U.K. revealed that in general, muscle from cattle, sheep and pigs is a valuable source of polyunsaturated fatty acids in the diet (Lawrie, 1998:260-267).

Comparison between current study and MRC food composition tables

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

$$25.6\text{ g} - 24.5\text{ g} = 1.1\text{ g}$$

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

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

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

Table 7:

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

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

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

Recommended Dietary Allowances

The Recommended Dietary Allowances (RDA) for males, aged 25 - 30 years (Whitney & Rolfes, 2002:1), were used as the reference point, to evaluate the possible nutrient contribution of lamb, as determined during this study. The RDA provides a benchmark for estimating nutrient needs of healthy people which should be met by the consumption of a variety of nutrient-rich food (Gericke, 2003:228). Three of the nutrients in cooked South African lamb provide more than a third of the RDA's for males aged 25 - 50 years per 100 g edible portion (Table 8). A 100 g portion of cooked shoulder, loin and leg lamb cuts provide on average 40 % protein, 37 % potassium and 39 % vitamin B_{12} of RDA for this group of males. Energy from a 100 g portion provides 6 % of the RDA. Lower levels of nutrients are included in the list namely vitamin B_3 provides 11.71 %, zinc 11.44 %, vitamin B_6 6.80 %. iron 6.09 %, vitamin B_2 4.15 %, and vitamin B_1 that represent 3.47 % of the RDA.

Table 8:

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

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

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

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

When the nutrient content of lean lamb (A2) is compared to that of beef, chicken and pork, the different species contain similar amounts of protein (25.01 – 30.9 g / 100 g) (Sayed, Frans & Schönfeldt, 1999). Lamb also provides all the essential amino acids in proportions that meet basic nutrient requirements. Cooked beef (A age, 4 % fat), however is the richer source of iron (1.99 mg / 100 g), zinc (4.45 mg / 100 g) and vitamin B_{12} (2.26 µg / 100 g) (Schönfeldt, Visser, Van Niekerk, and Van Heerden, 1996:94) compared to lamb. According to Lawrie (1998:260), with respect to species differences, the high content of iron in cooked beef reflects the greater concentration of myoglobin in this species than in lamb or pork. The cooked loin cut from lamb (± 7 % SCF) had the lowest iron content (0.62 mg / 100 g) and cooked white meat of chicken (42 days old) the lowest vitamin B_{12} (0.23 mg / 100 g) content according to Schönfeldt, Van Heerden, Van Niekerk, Visser, and Heinze (1998:27). Lamb contains a range of nutrients that contribute to its important place in a healthy diet.

Nutrient density and the Index of Nutritional Quantity

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

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

$$= 2.61$$

A value exceeding 1 indicates a good source of that nutrient. In Table 9, the majority of the values are above 1, confirming that three of the cooked lamb cuts, supply significant quantities of a range of protein, iron, zinc and vitamin B_{12} for a limited amount of energy. The more nutrients present and the fewer kiloJoules, the higher the nutrient density.

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

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

= 6.97 mg iron per 4200 kJ

Therefore:

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

= 1.74

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

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

Table 9:
Indices of the diet quality for cooked, deboned South African A2 lamb cuts

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

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

CONCLUSIONS

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

It is evident from this study that lamb also provides a variety of valuable nutrients. Another positive attribute of South African lamb is that it has a high mineral content. Meat from the A age class, fat class 2 lamb (± 7 % SCF) can be regarded as an important dietary source of the B vitamins, although some may be lost due to leaching during the cooking process. Lamb is undoubtedly an excellent source of nutrients that are required for good health. The results showed that there is variation in the micronutrient content between raw and cooked treatments of the three different lamb cuts analysed, especially for the proximate (chemical) analysis values and the minerals of the cooked cuts. Cooking affected mainly the protein magnesium, potassium and energy values, which were higher in the cooked meat cuts, but also differed significantly between the cooked cuts. There was no significant difference in the iron and zinc values between the cooked cuts. Results showed differences in both trace elements and B vitamins among different cuts, although the differences were not statistically significant.

Furthermore, A age class, fat class 2 lamb (± 7 % SCF) makes a valuable contribution to the RDA for males, aged 25 – 50 years, with regard to the protein, potassium, zinc, vitamin B_{12} and B_3 when included as part of a balanced meal plan. Therefore, it can be recommended that lean meat can be consumed in moderation and should be promoted as part of a healthy balanced diet.

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

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

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5

EFFECT OF FATNESS ON MEAT QUALITY OF THE LOIN CUT OF SA DORPER LAMB

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In this chapter the style and layout, as prescribed by the Journal in which the article will be published namely, Journal of Sensory Studies, has been followed

ABSTRACT

The effect of fat class (carcass fatness) on sensory quality, shear force and cooking loss was determined on the M. longissimus lumborum (M.LL) *(loin) of Dorper lambs. The muscle samples obtained from the M.LL (loin), (carcasses distributed over five fat classes, were sampled, chilled at 0 – 5 °C for 24 hours, aged at 4 °C for 7 days, and then frozen at – 20 °C). The samples were used to determine the sensory characteristics, cooking losses and shear force resistance measurements of the lamb meat. The cuts were cooked according to a dry heat cooking method in an oven set at a temperature of 160 °C, to an internal temperature of 70 °C.*

Total cooking loss had a high positive correlation with total drip loss (r=0.888) and fat mass (r=0.888). The percentage drip loss differed significantly between fat classes. Fat classes 1 and 2 differed significantly from fat classes 3 to 5 for total cooking loss in that it had a higher percentage cooking loss.

Quantitative descriptive sensory analysis was performed by a trained, ten-member panel, using an eight-point category scale. Sensory attributes evaluated were: aroma intensity, initial impression of juiciness, first bite tenderness, sustained impression of juiciness, muscle fibre and overall tenderness, amount of connective tissue (residue), overall flavour intensity, and off-flavour intensity followed a randomised complete block design.

According to the ANOVA results, two of the eight sensory attributes differed significantly ($p < 0.05$) *between the different fat classes. Initial impression of juiciness and sustained juiciness* *increased significantly (p* ≤ 0.029) with an increased fat class. *A positive correlation (r=0.739) existed between initial impression of juiciness and sustained impression of juiciness.*

A strong positive correlation was also found between the amount of connective tissue (residue) and first bite tenderness (r=0.887) as well as between the amount of connective tissue (residue) and tenderness (r=0.931). No significant differences were found by the trained taste panel for any of the texture attributes (first bite tenderness, residue and tenderness) between the five fat classes. The M. longissimus lumborum (M.LL) *muscles from the loin cuts were described as "fairly tender" by the panel.*

To conclude, results from this study revealed that cooking losses and juiciness were influenced by the amount of fat present in the M.LL *and contrary to what was expected, aroma, flavour and tenderness were not affected by the degree of fatness.*

Keywords: Fat class, meat quality characteristics, sensory, cooking loss, shear force, Dorper lamb.

INTRODUCTION

According to the South African national meat consumption survey of all nationalities and ethnic groups (n = 2481 households), performed by ACNielsen (2001), 16 % of the consumers ate lamb / mutton at least three times a week, with 10 % of the consumers never eating lamb / mutton. Older consumers (> 50 years) showed a greater decline in consumption of meat in comparison with their juniors. This could be attributed to various factors including the belief that eating red meat aggravates and / it causes "affluent diseases" such as heart disease (Scholtz, Vorster (jun), Matshego & Vorster, 2001:S39). Consumers' reluctance to include lamb in their diet can also be attributed to a specific taste perception ("lamb has a strong flavour"). Furthermore, lamb and mutton are perceived to be expensive, to contain high levels of cholesterol and to have a lower nutrient value than other meat products, although it is a protein-rich food. According to ACNielsen (2001), lamb was perceived as being lower in nutrients than other anima; protein choices. Poultry was rated to be the most nutritious source (60 %), followed by fish (49 %), beef (39 %) and lamb was only rated by 32 % of the consumers to be nutritious. Consumers demand consistent quality and lean meat with minimum fat required for flavour and juiciness (Ward, Trent & Hildebrand 1995:69). Therefore, the quality and quantity of fat in meat products are critical drivers of food choice. Consumers are increasingly interested in healthy products and prefer lean meat and carcasses (Cunhal-Sendim, Murillo, Belenguer. & Castello, 1999:190-191).

The consumer's opinion of the most tender meat choices was poultry (46 %), lam and mutton (34 %), fish (32 %) and beef (30 %) (ACNielsen, 2001). The ten factors that were considered the most important when purchasing meat (including beef, lamb, poultry and pork) were flavour (75 %), colour of meat product (48 %), amount of fat (45 %), price (36 %), tenderness (30 %), nutritional value (21 %), fresh products (not frozen) (20 %), packaging (17 %), classification (grading of meat cuts) (15 %) and preparation time (14 %) (Market Research Africa, 1996:15). According to Carpenter (1966:1235), consumers evaluate meat quality on the basis of aroma, juiciness, tenderness and flavour of the cooked meat, with tenderness being the most important attribute. Therefore, it is important to have sensory data on South African lamb to guide the consumer in their decision making

Texture, aroma and flavour characteristics are the main criteria used by consumers to evaluate the sensory quality of meat (Gorraiz, Beriain, Chasco & Iraizoz, 2000:137). Raw meat has little aroma and only a blood-like taste which could be affected by its pH, species, cooking method, type of cut and treatment prior to cooking (Bratzler: 1971:336, 344). The cooked aroma of meat can be described as the sensory attribute that represents certain volatile substances as perceived by the olfactory organ. According to Duckett and Kuber (2001), as cited by Ducket (2001:23), lamb fat has a very unique aroma.

The sensory attribute of juiciness, is determined by water retention and the lipid content of the meat, as well as by factors such as flavour and texture. For example, some flavour components in the fat and meat can cause the rapid release of saliva while chewing the meat, thus giving an impression of juiciness (Cross, Durland & Seideman, 1986:312). Marbling and fat around the edges of the cut of meat also help to retain water. The texture of meat determines the ease with which moisture can be expressed from the meat as it is being chewed and therefore contributes to the impression of juiciness (Cross *et al.,* 1986:312). Juiciness in cooked meat has two sensory phases (components) (Lyon & Lyon, 1989:335). The first impression of juiciness is the experience of wetness that is produced by the rapid release of meat fluid during the first few chews. Sustained impression of juiciness is largely due to the stimulatory effect of fat on salivation (Lawrie, 1998:182). The use of correct cooking methods and rate of heat penetration is another way of increasing (influencing) meat juiciness. Heat penetration is influenced by the rate at which energy is supplied and transmitted to the meat, the composition of the sample (lean, fat connective tissue and bone), the ratio and amounts of the sample as well as the characteristics of the surface where water loss and melting of fat appears (Paul & Palmer, 1972, Cross *et al*., 1986:308-309). Therefore it is important to keep in mind that there are multiple factors influencing the eating quality of meat products.

Flavour contributes to meat quality and can be described as the complex combination of the olfactory and gustatory attributes perceived during tasting. Meat flavour can be affected by age of the animal, water retention during cooking and fat within the muscle as well as fat on the surface of the meat cut (Shahidi, 1994:1-2). According to Duckett (2001:23), species-specific flavours are unique flavours that are located in the lipid-soluble (fat) fraction (branched chain fatty acids, carbonyl compounds, sulphur-containing compounds, lipid oxidation products and phenols) and are believed to impact on lamb and mutton flavour and odour. Maddock, McKenna and Savell (2003:184) noted that countries with high per capita consumption of lamb found lamb flavour and odour to be appealing attributes, whereas countries with low per capita lamb consumption found it unappealing.

The challenge is to make sure that high yield traits will not be promoted at the expense of eating quality. Therefore, the objective of this study was to compare the sensory attributes, as well as shear force resistance of the meat from lambs in five fat classes (Fat class 1 = ± 3 % SCF to fat class 5 with ± 16 % SCF) of Dorper *M. longissimus lumborum* (loin) lamb samples, using quantitative descriptive sensory analysis.

MATERIALS AND METHODS

Source of materials

In South Africa carcasses are classified according to age and fat class (National Department of Agricultural, Product Standards Act, ACT No. 119 of 1990, and its regulations). Age is described according to the number of permanent incisors with age class A = 0 tooth, AB = 1-2 tooth, B = 3-6 tooth and C = more than 6 tooth, while carcasses are grouped into seven fat classes by means of visual appraisal of subcutaneous fat (SCF) (fatness class 0 = less than 1.0 % SCF, to fat class 6 = more than 17.6 % SCF, excessively over-fat).

The lamb meat samples incorporated in this study (Table 1) comprised of the most commonly-consumed carcasses in South Africa (Van der Westhuizen, personal communication, 2003), namely the Dorper breed from five fat classes (Fat class 1 = ± 3 % SCF to a fat class 5 with ± 16 % SCF). The Dorper breed, a white-bodied sheep with a black head, was established in the 1940's, in the Karoo region of South Africa by crossing the Black Head Persian (a fat-rumped hair breed that is adapted to harsh arid environmental conditions) and the British Dorset Horn (Snowder & Duckett, 2003:368).

TABLE 1.
EXPERIMENTAL DESIGN FOR THE SENSORY EVALUATION OF A AGE CLASS, FAT CLASS 1-5 LOIN CUTS FROM SOUTH AFRICAN LAMB

Breed type	Dorper (wethers)				
Number of animals in study	66				
Starting weight (kg)	23 - 26				
Days on feed	90 – 120 days (4 - 6 months)				
Slaughter weight (kg)	30		36		42
Number of animals in slaughter group	20		24		20
Distribution of carcasses per fat class	1	2	3	4	5
	15	15	19	9	8
Sample	*M. longissimus lumborum* (loin cut) of the left sides				

On average, the animals were four to six months old and were fed intensively to obtain three different live weights (30, 36 and 42 kg) with a subsequent variation in carcass fatness (fat class 1-5). In this study, the animals were fed a high energy, high protein commercial feedlot diet on an ad lib basis and only Dorper lambs were included. All the male animals were slaughtered pre-puberty and no secondary male development was observed. On the day following slaughtering, carcasses were sectioned down the vertebral column by using a band saw. The loin cut (bone-in) containing the M.LL (the first to the last lumbar vertebra) of one side (left) of all carcasses were sampled from chilled carcasses, coded and labelled, vacuum packed and aged for seven days at 4 °C and then frozen at -20 °C until required for sensory evaluation.

Sensory analysis and cooking properties

The cuts were prepared and evaluated according to the American Meat Science Association and National Livestock and Meat Board (1995:7-8) research guidelines on the cooking and sensory evaluation measurements of fresh meat. The M. LL cuts were thawed over a 24 hour period at 4 °C before cooking. The samples were prepared according to a standardized dry heat cooking method in identical Mielé ovens (Mielé ovens, model H217) The dry heat cooking method entailed the oven roasting of meat, uncovered on a flat open pan, with a rack to keep the meat out of the drip. No water (liquid) was added during the cooking of the meat in the oven at a temperature of 160 °C to an internal meat temperature of 70 °C (45 minutes per kilogram). A hand-held digital probe (model Kane-May 1012) was used to record the internal temperature at the geometric centre of the meat (American Meat Science Association, 1995:7-8). Cooking losses (thawing loss, drip loss, evaporation loss and fat mass calculated from the total volume of fat according to the following: volume fat x 0.9 g / ml were measured as part of the standard procedure (Annexure 1). After cooking, all samples rested at room temperature (centrally controlled at 22 °C), for 10 minutes. The M. LL muscle was then removed from the bone and halved (transverse). One half was used for sensory analysis and the other half of the cut was used for shear force measurements. Ten cubed samples (10 mm x 10 mm x 10 mm) were cut from the middle of the muscle half and immediately wrapped individually in pre-coded (with 3 - digit random numbers) aluminium foil squares (9 cm x 9 cm). These samples, were served warm (± 40 °C) on pre-warmed plates to a trained sensory panel within 20 minutes from the time the cut was removed from the oven.

Sensory panel procedures

An external experienced trained sensory panel consisting of ten members was used for sensory analysis at the Meat Industry Centre (ARC-Irene). The sensory analysis facility contains all the elements necessary for an efficient sensory program and was originally constructed according to the American Society for Testing and Material's (ASTM, 1989:15) design guidelines for sensory facilities. During the four-day training sessions (two hours per day), panellists received representative samples of each of the different treatments (fat codes) of Dorper loin one at a time. They were trained in order to increase their sensitivity and ability to discriminate between specific samples and the sensory attributes of each sample. A clear definition of each attribute was developed, based on ASTM to describe the specific product attribute (lexicon) to be evaluated (Table 2). A score sheet, using a eight-point category rating scale was used. Each sensory category attribute was verbally labelled, e g. eight indicated extremely tender and juicy meat, extreme flavour and aroma intensity and no residue, while one referred to extremely tough and dry meat, extremely bland flavour and aroma intensity and excessive residual connective tissue (Meilgaard, Civille & Carr, 1991:53-55). The following sensory quality characteristics were evaluated: aroma intensity, initial impression of juiciness, first bite tenderness, sustained impression of juiciness, muscle fibre and overall tenderness, amount of connective tissue (residue), overall flavour and off-flavour.

TABLE 2.
DESCRIPTION OF EACH ATTRIBUTE AS USED BY THE TRAINED SENSORY PANEL TO EVALUATE THE LAMB SAMPLES

Attributes	Instructions and Lexicon
Aroma Intensity	Take a few short sniffs as soon as you remove the foil. This aroma is associated with cooked lamb and has an important influence and contribution to the flavour of the cooked lamb cut.
Initial impression of juiciness	It is the amount of fluid exuded on the cut surface when pressed between thumb and index finger.
Sustained juiciness	The impression of juiciness that is formed when chewing. It is either dry with no fluid or juicy with moisture.
First bite tenderness	The impression of tenderness of the meat when biting into the meat is formed during the first bite.
Muscle fibre and overall tenderness	Chew sample with a light chewing action. The impression of tenderness of the meat when chewing, and evaluating whether the meat breaks easily between the teeth (tender) or has become tough/difficult to bite through.
Amount of connective tissue (residue)	Chew sample with a light chewing action. This is the chewiness of the meat.
Overall flavour	The combination of taste while chewing and swallowing the sample.
Off-flavour	Flavour not associated with lamb.

Two evaluation sessions per day, with three samples served in every session over 11 days were conducted. During a tasting session, 3-digit coded samples representing one of the different treatments were served randomly to the individual panellists. The ten panellists were seated in individual sensory booths to ensure unbiased objectivity and consistent responses, without being influenced by external factors. In order to ensure that the panel members did not suffer from sensory fatigue, a short break of 20 minutes was introduced between the two tasting sessions per day. For each session, samples were evaluated under red light conditions to mask possible colour differences and were presented on a preheated (100 °C) glass plate. Water at room temperature was provided to cleanse the palate between samples.

Shear force resistance measurement

The meat portion (remaining half of the cut) allocated to shear force resistance evaluation, was cooled covered and kept in a refrigerator (4 °C) overnight (12 hours). Subsequently the samples were removed from the refrigerator and allowed to reach room temperature (centrally controlled at 22 °C) before being cored. Eight cylindrical samples with a diameter of 12.7 mm were removed parallel to the grain of the meat. One shear value from each core (perpendicular to the fibre direction) was obtained using an Instron Universal Testing Machine (Model 4301) (Instron Corporation, 1990) with a Warner-Bratzler shear force device mounted on a Universal Instron apparatus. The reported value in kg force represented the average peak force measurement.

STATISTICAL ANALYSES

Data was statistically analysed using the GenStat for Windows (2000) statistical computer program. The significance of all the sensory attributes measured for each fat class of the Dorper loin cut was tested by means of analysis of variance (ANOVA), using a split plot design which tested the main effect of the sample, panellists, as well as the sample-by-panellist interactions at a 5 % level of significance. If the sample main effect was significant, Fisher's protected t-test least significant difference (LSD) was applied to separate the sample means. A correlation matrix was constructed to test for significant correlations between attributes (Annexure 3).

A multivariate statistical analysis technique, Principal Component Analysis (PCA) was performed to reduce a large set of variables into a much smaller set of composite variables, the principal components, that explains most of the variance in the population of samples. The PCA is a graphical presentation of the data and is used to better classify and group samples using the sensory variables (Shaw, Moshonas, Buslig, Barros & Widmer, 1999:1951). PCA is discussed according to the sensory attributes measured in the loin samples which explain most of the variation found in the entire data set.

RESULTS

The fatness of the various loin cuts from five fat classes had an effect on the following cooking-related variables significantly: total cooking loss (%), drip loss (%) and cooked fat mass (g) (Table 3). The percentage total cooking loss, drip loss and cooked fat mass of the loin cuts increased significantly with the increase in carcass fatness. Variation in total cooking loss was the result of variation in drip loss, as evaporation loss was not influenced by carcass fatness. Drip loss in fat class 5 was almost four times higher compared to fat class 1 and almost double as much as fat class 2. According to the ANOVA, no significant differences were found ($p < 0.05$) in the percentage thawing loss, evaporation loss and drip loss (density) of the loin cuts of the five fat classes indicating that fat class probably only have a significant effect on the total cooking loss and cooked fat mass (calculated from the total volume of cooked fat).

The results, as obtained from the sensory panel, for the Dorper loin cuts from five fat classes are summarized in Table 3. Two of the eight sensory attributes differed significantly ($p < 0.05$), namely initial impression of juiciness and sustained juiciness. No significant difference ($p < 0.05$) was found for the aroma of the loin cut for the five fat classes. The aroma was described as fairly intense (range 6.08 – 6.21).

TABLE 3.
LEAST SQUARE MEAN VALUES FOR THE SENSORY ANALYSIS OF DORPER LOIN CUT SAMPLES (N=66)

Sensory attributes	p-value	Fat class 1 ±3 % SCF	Fat class 2 ±7 % SCF	Fat class 3 ±10 % SCF	Fat class 4 ±13 % SCF	Fat class 5 ±16 % SCF
Fat thickness (mm)	< 0.001	0.650 ±0.426	2.193 ±0.411	4.353 ±0.365	5.178 ±0.531	7.550 ±0.563
Aroma Intensity	0.910	6.21 ±0.108	6.21 ±0.108	6.12 ±0.096	6.08 ±0.140	6.16 ±0.148
Initial impression of juiciness	0.002	5.73[a] ±0.106	6.12[ab] ±0.106	6.19[ab] ±0.094	6.43[b] ±0.136	6.15[ab] ±0.145
First bite tenderness	0.334	5.93 ±0.161	6.33 ±0.161	6.23 ±0.143	6.38 ±0.208	6.03 ±0.221
Sustained juiciness	0.029	5.20[a] ±0.129	5.50[a] ±0.129	5.63[ab] ±0.115	5.87[b] ±0.166	5.44[a] ±0.176
Muscle fibre and overall tenderness	0.701	6.05 ±0.169	6.34 ±0.169	6.23 ±0.150	6.36 ±0.218	6.09 ±0.231
Amount of connective tissue (residue)	0.855	5.87 ±0.139	6.05 ±0.139	6.98 ±0.124	6.01 ±0.180	5.85 ±0.191
Overall flavour	0.943	6.01 ±0.087	6.07 ±0.087	6.10 ±0.077	6.08 ±0.112	6.02 ±0.119
Off flavour	0.259	6.80 ±0.169	6.98 ±0.169	7.23 ±0.150	7.29 ±0.218	7.24 ±0.231
Objective tenderness measurement						
Shear force measurement (kg force)	0.992	2.60 ±0.207	2.56 ±0.207	2.61 ±0.183	2.73 ±0.267	2.62 ±0.283
Cooking-related properties						
Total cooking loss (%)	< 0.001	11.88[a] ±0.622	13.35[a] ±0.622	15.25[b] ±0.552	15.59[bc] ±0.803	17.14[c] ±0.851
Thawing loss (%)	0.764	0.229 ±0.050	0.253 ±0.050	0.198 ±0.045	0.198 ±0.065	0.146 ±0.069
Drip loss (%)	< 0.001	1.86[a] ±0.390	3.59[b] ±0.390	5.38[c] ±0.346	6.22[c] ±0.503	7.79[d] ±0.534
Evaporation loss (%)	0.650	10.02 ±0.325	9.75 ±0.326	9.87 ±0.290	9.38 ±0.421	9.34 ±0.446
Cooked fat mass (g) (calculated) (total volume of fat)	< 0.001	3.67[a] ±5.10	17.73[a] ±5.10	38.71b ±4.53	59.70cd ±6.58	76.27[d] ±6.98

p-value: F-probability to test for significant differences between samples
Means with different letters (a, b, c or d) are significantly different ($p \leq 0.05$) within row
±: These values are standard error of least square means
Sensory ratings: Sensory ratings: Each sensory category attribute was verbally labelled, e g. eight indicated extremely tender and juicy meat, extreme flavour and aroma intensity and no residue, while one referred to extremely tough and dry meat, extremely bland flavour and aroma intensity and excessive residual connective tissue (Meilgaard, et al. 1991).
SCF: Subcutaneous fat

With regard to the significant difference of the initial impression of juiciness, samples from fat class 1 were described by the trained panel as slightly juicy (5.73) compared to fat class 4 that was rated to be fairly juicy (6.43). Although small, a significant difference (p = 0.029) was found between the five fat classes for sustained juiciness. Samples from fat class 1, 2 and 5 were less juicy (initial impression of juiciness and sustained impression of juiciness) than the other fat classes but only significantly different between fat class 1 and 4 (initial impression of juiciness).

No significant differences were found by the trained taste panel in any of the texture attributes (first bite tenderness, residue and tenderness). No significant differences ($p = 0.992$) were found in the shear force values of the loin cuts of the five fat classes. The shear force values (Table 3) were the lowest for fat class 2 (2.56 kg force and the highest for fat class 4 (2.73 kg force), and therefore tender. This correlates with the tenderness attribute evaluated by the panel. In general, the loin cuts were described as fairly tender (scores of 6.05-6.36).

No significant differences ($p < 0.05$) were found by the trained panel for the two flavour attributes. The overall flavour of the loin cuts were described as fairly intense (6.01 – 6.10) and the off-flavour as very intense as described (scores of 6.80-7.24).

Relationship between attributes

Correlations with values higher than 0.7 were investigated. Generally, a correlation coefficient (r) of approximately 0.7 is regarded as indicating a fairly strong correlation (Rayner, 1969). Refer Annexure 3.

A positive correlation existed between initial impression of juiciness and sustained impression of juiciness ($r = 0.739$). Strong positive relationships were found between tenderness and first bite tenderness ($r = 0.929$); first bite tenderness and connective tissue (residue) ($r = 0.887$); and connective tissue (residue) and tenderness ($r = 0.931$).

A strong positive correlation existed between percentage total cooking loss ($r = 0.734$) and the total fat mass ($r = 0.734$). The total percentage drip loss correlated strongly with fat mass (total volume of fat) ($r = 0.888$), fat mass ($r = 0.888$) and total cooking loss ($r = 0.907$). This is an indication that the total cooking loss consists mainly of fat and that evaporation loss is consistent, as shown in Table 2.

Multivariate statistical analyses: Principal Component Analysis

The interpretation of descriptive sensory evaluation data is often simplified with the assistance of multivariate statistical procedures such as Principal Component Analysis (PCA) and Canonical Variate Analysis (CVA). PCA is a statistical procedure that identifies the smallest number of latent variables, called principal components that explain the greatest amount of observed variability. It is possible to explain 75 – 90 % of the total variability in a data set containing 25 - 30 variables with as few as two to three principal components. Through PCA, the correlation structure of a group of multivariate observations is analysed and the axis along which maximum variability of the data occurs is identified and referred to as the first principal component or PC1 (horizontal axis). The PC2 (vertical axis) is the axis along which the greatest amount of the remaining variability lies subject to the constraint that the axes must be perpendicular (at right angles) to each other (Meilgaard *et al.*, 1991: 277).

PCA was performed on the full data set obtained from sensory analysis (aroma, juiciness first bite tenderness, tenderness, residue and off flavour), cooking-related properties and shear force values (see Figure 1). The first two principal components of the PCA (Figure 1) accounted for 77.3 % of observed variability. The first principal component (PC1) accounted for 40.0 % of the total variation in the data with a latent root of 4.00. The main variates discriminating between the five fat classes of the lamb loin cut in PC1 (horizontal axis) were, first impression of juiciness (r = 0.893); tenderness (r = 0.889); residue (r = 0.881) as well as sustained impression of juiciness (r = 0.797). The second principal component (PC2) accounted for 37.30 % of the total variation with a latent root of 3.73. For PC2 (vertical axis) drip loss (r = -0.950), fat mass (r = -0.936) and total cooking loss (r = -0.862), were the main variates discriminating between the five fat classes.

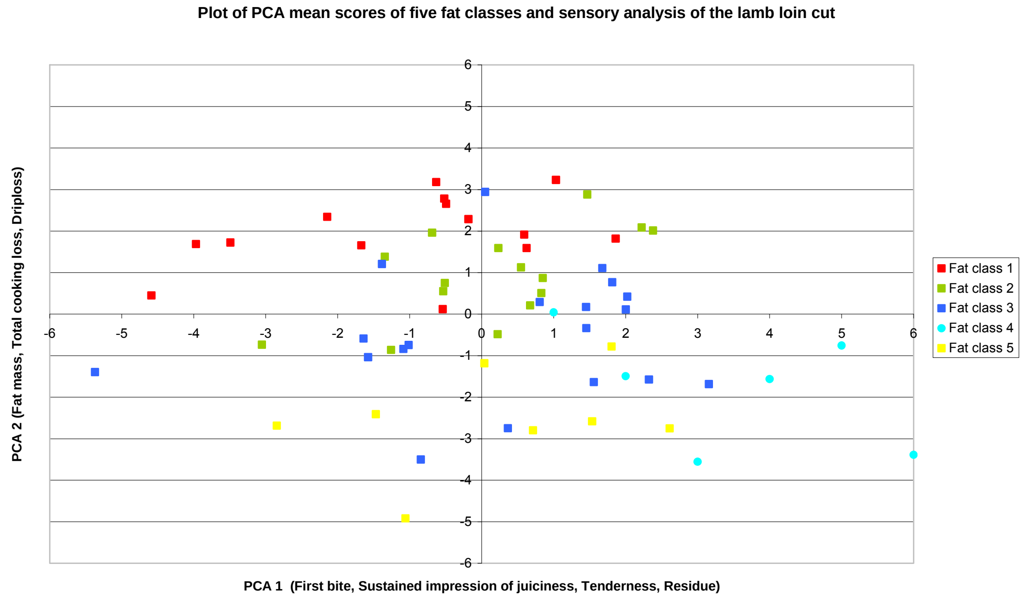

FIGURE 1: PRINCIPAL COMPONENT ANALYSIS: DISCRIMINATION OF LAMB LOIN CUTS FROM FIVE FAT CLASSES ON SENSORY AND COOKING RELATED PROPERTIES AS WELL AS SHEAR FORCE

These results were confirmed by the ANOVA. According to the results summarized from the ANOVA and the graphical presentation (Figure 1) for PC1, of the sensory attributes of the lamb loin cuts for the five fat classes, fat class 1 contrasted the strongest with fat class 4. Fat class 1 was slightly juicy for the initial impression of juiciness (5.73) as well as for the sustained impression of juiciness (5.20) and fat class 4 was rated fairly juicy (6.43) for initial impression of juiciness and slightly juicy for sustained impression of juiciness (5.87). Fat classes 1 and 5 were rated to be fairly tender (6.05, 6.09) with a slight amount of residue (5.87, 5.85), and fat class 3 and 4 were evaluated as having traces of connective tissue (6.98).

With regard to the percentage total cooking loss in PC2 fat class 1 and 2, again contrasted with fat class 3, 4 and 5. Fat class 1 had the lowest percentage cooking loss (11.88) compared to fat class 5 that had the highest percentage cooking loss (17.14) of the five fat classes. The same trend was followed for the percentage drip loss. Fat class 1 had the lowest percentage drip loss (1.86) compared to fat class 5 that had the highest percentage drip loss (7.79) of the five fat classes.

DISCUSSION

This study confirms the fact that, during growth and development, certain significant changes occur in the composition of the body of the animal which have a direct effect on the palatability of the end-product as evaluated by the consumer. Differences detected in the meat quality between the five fat classes of the loin cut were small (only the two juiciness attributes differed) more differences were found for the total cooking loss, drip loss and cooked fat mass of the loin cut. The significant increase in sustained juiciness between the samples from different fat classes could be due to the stimulatory effect of the fat on salivation and also explain why the meat gives an initial impression of juiciness (Lawrie, 1998:182). According to Bratzler, (1971:334) the sensation of juiciness in cooked meat is closely related to fat content. The results from this study are different to those by Péreze, Maino, Tomic, Mardones and Pokniak, (2002:237) who found that juiciness did not differ between fat groups. Schönfeldt (1989:208) also found that with an increased fatness, the juiciness of the cooked cuts tends to decrease. According to Lawrie (1998:183), the process of freezing does not affect juiciness and therefore it can be assumed that differences in juiciness must be attributed to other factors such as fatness level, breed and treatment before slaughter, the length of storage or cooking method.

The overall flavour of the loin cuts was described by the trained panel as fairly intense with a very intense off-flavour although there was no significant difference between the fat classes. Shahidi, (1994) also reported that fat cover has no significant effect on sheep meat flavour. On the other hand, Shahidi, (1994) mentioned that off-flavours in lamb were common when sheep had soft oily fat arising from a high energy-diet, which might be the reason for the high off-flavour rating in this trail where the animals were fed a high energy, high protein commercial feedlot diet. However, it was not tested in this study. The fact that the aroma, flavour and off-flavour attributes did not differ significantly from each other between the five fat classes in this study can be attributed to the fact that the lambs were younger than 16 months. According to Channon, et al. (2003) the aging effect on sheep meat odour and flavour may not be obvious until animals are much older. Jeremiah (1998) who reported that the role of fatness in lamb quality and its relationship to palatability is not well understood and is still a contentious issue also supports these findings. Nutritional regimen can impact on fat composition and therefore flavour ratings as well. In this study the animals were fed a high energy, high protein commercial feedlot diet on an *ad lib* basis and only Dorper lambs were included. Duckett (2001:23) reported research indicating that genetics had a minor influence on lamb flavour but, however, interactions between breed and nutrition may occur. Young, Reid, Smith, and Braggins (1994:84) concluded that there was no consensus between the cause of the typical flavour and odour of sheep meat. This is also applicable to this study, as all samples are from young grain-fed fed animals.

The sensory panel for this study rated the lamb samples fairly tender (6.05-6.36) (Table 2) and these results were similar to those reported by Péreze *et al.* (2002:237) who found lamb meat as fairly tender. Parrish (1974:119) found that the degree of marbling had little effect on tenderness however the cooking loss increased with increased marbling. According to Savell & Cross (1986:3) there is a high significant correlation between tenderness and fat content of the longissimus muscle.

Warner-Bratzler shear force resistance measurements are an objective measure of tenderness used to evaluate relative differences in tenderness or toughness of meat. In general, the overall shear force values reported in the literature (Duckett, 2001:22) for lamb are lower than for most beef values. In beef (broiled chops, cooled and four half-inch cores were used) the threshold values for shear force is considered to be around 4.5 kg force. Values below 4.5 kg force (threshold) would indicate that consumers would rate it slightly tender or better in overall tenderness. Prior to this study, no threshold values were available for lamb, but based on shear force values for tenderness reported for beef, it can be concluded that consumers would consider similar lamb shear force values acceptable and palatable (Duckett, 2001:22). Results from this study correlate well with the values obtained by the sensory panel. The taste panel evaluated the loin cuts from all five fat classes to be fairly tender with traces of connective tissue (residue). Shear force resistance results in the present study showed an average value of 2.6 kg force for the Dorper loin chops from five fat classes which could be considered as highly acceptable, taking into consideration that values for beef of < 4.5 kg force is proven to be acceptable to the consumer. According to results from Schönfeldt (1989:208), a low resistance to shear force with increased fatness may be attributed to the increased muscle volume relative to the structural component, although the mechanism of toughening is not yet understood. Meat from animals of the A age groups showed less resistance to shear force according to the study conducted by Schönfeldt (1989:207).

Variation in total cooking loss was the result of variation in drip loss (increased with increase in fat class), as evaporation loss was not significantly influenced by carcass fatness. Drip loss in fat class 5 was almost four times higher than fat class 1 and almost twice as much as fat class 2. The differences in cooking loss can be attributed to the increase in fatness over the five fat classes. This is in accordance with results from Solomon, Kemp, Moody, Ely and Fox (1980:1106), and Schönfeldt (1989:208), who described differences in cooking losses amongst roasts cooked under similar conditions as primarily due to differences in fatness, with leaner roasts generally having more evaporation loss while roasts with a higher fat content having more drip loss. Carpenter and King (1965:103) also reported higher cooking losses with increased marbling or intramuscular fat content. Although Parrish (1974:118) found that the degree of marbling had little effect on the flavour, tenderness, juiciness, overall acceptability and Warner-Bratzler shear force, they reported a higher percentage total cooking loss, with increasing amount of marbling. Ockerman, Emsen, Parker and Pieterson (1982:1368) also found a negative relationship between cooking yield and fat content.

CONCLUSION

The focus of the present study was on the differences in the sensory attributes of the *M. longissimus lumborum* (loin) as effected by the fat class. There are numerous factors that may affect quality, texture and flavour of lamb and sheep meat such as age, fat class, breed, nutrition and sex. However, from this study it seemed as if differences were smaller because only one age group was investigated. With the exception of juiciness, the results in this study showed that contrary to expected carcass fatness (in the same age over five fat classes), as portrayed in the SA Classification system, does not have a significant effect on the sensory qualities of *M. longissimus lumborum* (loin) from lambs of the same age.

The study found that meat cuts within the same age (A age class, fat class 2) do not differ significantly from each other in tenderness. Meat from animals in the same age (A2) with increasing fat classes (up to 16 % SCF) is juicier with a higher percentage total cooking loss.

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Annexure 1

LAMB COOKING DATA FORM

DRY HEAT COOKING METHOD (OVEN ROASTING)

CUT:………………………………….DATE:………………………..	
Taste panel leader:……………………… Taste panel assistant…………………… Panel date:………………………… Sample code: …………………… SE code:……………………………....	
THAWING DATA	
Mass raw sample + thawing loss + bag Mass bag + exudates Mass bag without exudates	**……………..g** **……………..g** **……………..g**
COOKING DATA	
Time in:…………………… Cooking time (h) Time out:………………….. (calculated)……………… Thermocouples: Number…………….Start temp…………………End temp:………… Oven: no………. Sample:……………°C ……………°C ...…………..°C ……………°C Cooking tempo (calculated):………………(°C/g/min)	
	Mass (g)
Mass of pan + rack Mass pan + rack and raw meat Mass raw meat (calculated (g)) Mass pan + rack + drip loss + cooked meat Mass pan rack + drip loss Mass total drip loss (calculated (g)) Mass cooked meat (calculated (g)) Mass pan + rack + residue drip Mass residual drip loss in pan (calculated (g))	**……………..g** **……………..g** **……………..g** **……………..g** **……………..g**
CYLINDER READING	
Total drip loss Stock Fat Total volume of fat (calculated (ml)) Mass of fat ((g) (calculated, volume fat X 0.9 g/ml)	**……………..g** **……………..g** **……………..g**
Thawing loss (calculated) Evaporation loss (calculated) Drip loss (calculated) Total cooking loss (calculated)	

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Annexure 2

SCORE SHEET
Sensory analysis of South African Dorper lamb

Name:……………………………………………. **Date:………………………………**
Panellist no:……………………………………..
Please evaluate the following samples of LAMB for the designated characteristics.

Attribute	Rating scale	Sample codes			
AROMA INTENSITY Take a few short sniffs as soon as you remove the foil	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
INITIAL IMPRESSION OF JUICINESS The amount of fluid exuded on the cut surface when pressed between thumb and forefinger	1 = Extremely dry 2 = Very dry 3 = Fairly dry 4 = Slightly dry 5 = Slightly juicy 6 = Fairly juicy 7 = Very juicy 8 = Extremely juicy				
FIRST BITE TENDERNESS The impression that you form on the first bite tenderness	1 = Extremely tough 2 = Very tough 3 = Fairly tough 4 = Slightly tough 5 = Slightly tender 6 = Fairly tender 7 = Very tender 8 = Extremely tender				
SUSTAINED IMPRESSION OF JUICINESS The impression of juiciness that you form as you start chewing	1 = Extremely dry 2 = Very dry 3 = Fairly dry 4 = Slightly dry 5 = Slightly juicy 6 = Fairly juicy 7 = Very juicy 8 = Extremely juicy				
MUSCLE FIBRE & OVERALL TENDERNESS Chew sample with a light chewing action	1 = Extremely tough 2 = Very tough 3 = Fairly tough 4 = Slightly tough 5 = Slightly tender 6 = Fairly tender 7 = Very tender 8 = Extremely tender				
AMOUNT OF CONNECTIVE TISSUE (RESIDUE) The chewiness of the meat **(note the scale is reversed**	1 = Extremely abundant 2 = Very abundant 3 = Excessive amount 4 = Moderate 5 = Slight 6 = Traces 7 = Practically none 8 = None				
OVERALL FLAVOUR INTENSITY This is the combination of taste while chewing and swallowing	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				
OFF FLAVOUR This is the flavour not associated with lamb	1 = Extremely bland 2 = Very bland 3 = Fairly bland 4 = Slightly bland 5 = Slightly intense 6 = Fairly intense 7 = Very intense 8 = Extremely intense				

Annexure 3

Correlation matrix of sensory data of the A age class, fat class 1-5 for the loin cut of the South African Dorper lamb

Aroma intensity	1	1.000															
Initial impression of juiciness	2	0.010	1.000														
First bite tenderness	3	-0.059	0.400	1.000													
Sustained impression of juiciness	4	-0.161	0.739	0.568	1.000												
Tenderness	5	-0.109	0.339	0.929	0.551	1.000											
Residue	6	-0.124	0.357	0.887	0.538	0.931	1.000										
Overall flavour intensity	7	0.346	0.089	0.253	0.222	0.238	0.201	1.000									
Off flavour	8	-0.463	0.186	0.235	0.137	0.218	0.197	-0.427	1.000								
Shear force	9	0.237	-0.285	-0.554	-0.510	-0.567	-0.613	-0.104	-0.090	1.000							
Drip density	10	-0.173	0.025	-0.067	-0.042	-0.061	-0.046	-0.128	0.228	0.052	1.000						
Fat volume	11	0.028	0.270	-0.010	0.170	-0.032	-0.053	-0.024	0.231	0.157	0.379	1.000					
Fat mass	12	0.028	0.270	-0.010	0.170	-0.032	-0.053	-0.024	0.231	0.157	0.379	1.000	1.000				
Total cooking loss	13	-0.036	0.189	-0.007	0.071	-0.004	-0.057	-0.082	0.267	0.162	0.389	0.734	0.734	1.000			
Drip loss	14	0.021	0.264	-0.007	0.125	-0.029	-0.068	-0.031	0.225	0.177	0.337	0.888	0.888	0.907	1.000		
Evaporation loss	15	-0.124	-0.073	-0.004	-0.077	0.047	-0.001	-0.130	0.184	0.031	0.253	-0.015	-0.015	0.570	0.170	1.000	
Thawing loss	16	0.176	0.073	-0.010	-0.068	-0.042	-0.061	0.075	-0.161	-0.114	0.234	-0.187	-0.187	-0.082	-0.135	0.070	1.000
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**

6

CONCLUSION AND RECOMMENDATIONS

With increasing consumer demand for lean meat, the relationship between fatness and eating quality as well as healthy lean meat portions has become the focus point for the red meat industry lately. The carcass composition (cutting data) in this study provides retailers with an insight into the variation in subcutaneous fat (SCF) of the different cuts of the carcass at different fat levels (fat scores). If the data is combined with efficient trimming skills of innovative retail operations, carcasses over a broad spectrum of fat levels could be processed into higher-value cuts that are more acceptable and attractive to the consumer. Trimming of visible fat in some cuts can result in less fat (10 g) per 100 g meat and can then be included in low fat diets.

In some instances, depending on the price of the carcass and the cost of trimming (labour and value of trimmed fat), further processing of over fat carcasses, can provide more affordable cuts to the consumer. On the other hand a certain sector of the consumer corps may be willing to pay premium prices if the final product is perceived as being healthier and this could perhaps justify the trimming of any cut to consumer standards. A limitation of this part of the study is the fact that no measurement was made of the amount of intermuscular or intramuscular (seam) fat. It could provide proper information on how much intermuscular fat could be expected to be present in the different cuts. Previous work has showed that excessive fat may still remain in certain cuts of over fat carcasses trimmed of SCF. Therefore, further investigation into the remaining fat of different cuts at different fat levels after trimming could be valuable, when decisions on trimming for specific markets are made. Consumer perceptions on the trimmed product vs. the price should also be investigated.

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

It is evident from this study that lamb also provides a variety of valuable nutrients. Meat from the A age class, fat class 2 lamb (± 7 % SCF) is nutrient dense and can be regarded as an important dietary source of the B vitamins, although some may be lost due to leaching during the cooking process. Lamb is undoubtedly an excellent source of nutrients (protein, zinc, iron magnesium and the B-group vitamins) that are required for good health and meat from the A2 lamb (± 7 % SCF) makes a valuable contribution to the RDA for males, aged 25 – 50 years. Although there is no RDA for cholesterol the recommended maximum daily cholesterol guideline is less than 300 mg per day. Results from the study showed that a 100 g portion of cooked shoulder provides 85 mg cholesterol and a 100 g portion of cooked loin cut, 86 mg and the leg cut 91.7 mg. Therefore it can be recommended that a person can eat a 100 g of A2 lam in moderation as part of a healthy diet programme.

Another approach to good nutrition has been proposed namely Index of Nutritional Quality (INQ). If a food has an INQ of two or more for two nutrients or one or more for four nutrients, it makes a significant contribution to the total nutrient intake and therefore should be regarded as ”nutritious” (Guthrie & Picciano, 1995:53). SA Lamb (A age class, fat class 2) contributes significant to the INQ in that three of the nutrients (protein, zinc and vitamin B_{12}) in the leg, loin and shoulder cuts are >2 and the lamb can thus be regarded as “nutritious”. The leg and shoulder cuts each have 2 nutrients [(protein and cyanocobalamin (vit B_{12})] that are >2, and four nutrients [(protein, iron, zinc and cyanocobalamin (vit B_{12})] that are >1 and can therefore be regarded as nutritious because it makes a significant contribution to the total nutrient intake (Guthrie & Picciano, 1995:53).

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

The results demonstrated that meat varies in its contributions to the diet, mainly due to the sources of the data (Annexure 1). When comparing South African food composition (lamb) data with the current data included in the South African food composition tales (Sayed, Frans & Schönfeldt, 1999) it is clear that there are large differences in the nutrient composition of lamb between these two sets of data. This illustrates that the use of non-local data sources can produce differences in the assessment of its nutrient composition and may cause conflicting interpretations of dietary intakes. On average lamb from South African A age class, fat class 2 lamb contained less fat, energy, magnesium, sodium, zinc and iron when compared to the values in the MRC tables (previous lamb data). It is also lower in water-soluble vitamins nutrients, monounsaturated fatty acids as well as polyunsaturated fatty acids.

Local data on nutrient composition is important for assessing dietary intakes, determining the relationship between dietary intake and disease occurrence, and for communicating meaningful nutrient information to the consumers. This study contributes valuable data to more accurate dietary intake by providing a more precise nutrient profile of South African lamb. However, this data is on A age class, fat class 2 lambs only (± 7 % SCF), and more research and data is required on the other age and fat classes ensure a complete data set of South African lamb and mutton.

Meat quality is a multi-dimensional phenomenon and is influenced by a wide range of factors which can exert their effect from the animal to the plate. Focusing on the sensory attributes, meat is a favourite food in South Africa, therefore taste, aroma and texture are important sensory characteristics that contribute to the palatability of lamb (meat). However, there are numerous factors that may affect the quality, texture and flavour of lamb and sheep meat such as age, fat class, breed, nutrition and sex. From this study it seemed as if differences were smaller because only one age group was investigated. With the exception of juiciness, the results in this study showed that contrary to expected carcass fatness (in the same age over five fat classes), as portrayed in the SA Classification system, does not have a significant effect on the sensory qualities of *M. longissimus lumborum* (loin) from lambs of the same age. The study found that meat cuts within the same age (A age class, fat class 2) do not differ significantly from each other in tenderness. Meat from animals in the same age (A2) with increasing fat classes (up to 16 % SCF) is juicier with a higher percentage total cooking loss.

It can be concluded that the consumer will still have a palatable and nutritious product if some of the excess fat is trimmed from certain cuts. This conclusion is based on the results of this study, and only measured in the A age animals. It should be further investigated on all the other age groups and fat classes to determine the influence of age on the eating quality of lamb and mutton. It is recommended that the nutrient composition of the other age classes such as AB age (young animals with 1-2 incisors), B age (older animals with 3-6 incisor) and C age (the oldest animals with 7-8 incisors) (especially for Mutton Merino) also be analysed, to have representative physical and nutrient content values for food composition tables on South African lamb and sheep meat.

If it is considered that, in general, this study found a significant difference in previously-believed-to-be-accurate values, it is important to the Red Meat Industry to support further analysis of the nutrient composition of South African lamb and sheep. A further recommendation is to determine the Conjugated Linoleic Acid (CLA) content of A2 lam because ruminant meat is a natural source of CLA as CLA is produced in the ruminant and according to Mulvihill, (2001) lamb contains on average the most CLA. The dissemination of the information concerning the quality of South African lamb (carcass, nutrient and sensory attributes) to consumers, the meat industry and health workers is of the essence and therefore recommended.

From the results of this study, it is clear that the null hypothesis, that stated that there will be no differences in the carcass, nutrient and sensory attributes of selected raw and cooked cuts of the A age class South African lamb, can be rejected.

Annexure 1

TABLE 1: INDICATION OF THE ABSOLUTE DIFFERENCES OF THE NUTRIENT COMPOSITION FOR THREE COOKED CUTS AS WELL AS FOR RAW AND COOKED LEAN (MEAT) ONLY LAMB BETWEEN THE SOUTH AFRICAN 1999 MRC FOOD COMPOSITION TABLES AND THE RESULTS OF THE CURRENT STUDY ON THE A AGE CLASS, FATNESS 2 LAMB

PER 100 G EDIBLE PORTION F	ABSOLUTE DIFFERENCE		ABSOLUTE DIFFERENCE		
NUTRIENTS ANALYSED	**RAW**	**COOKED**	**SHOULDER COOKED**	**LOIN COOKED**	**LEG COOKED**
PROXIMATE ANALYSIS:					
Moisture	10.8	14	47	23	14
Protein (Nx6.25)	1.4	-1.4	-19	10	-4
Fat	-12.59	-12.96	-59	-66	-54
Ash			-	-	-
Food energy (calculated)	-443	-1891	-46	-41	-31
MINERALS:					
Magnesium (Mg)	-1.9	-2.3	-25	0.83	-5
Potassium (K)	131	2	5	0.92	-3
Sodium (Na)	-146.6	-1.3	-8	8.18	-6
Zinc (Zn)	-1.08	-3.03	-80	-37	-61
Iron (Fe)	-0.64	-1.43	-	-1.2	-40
VITAMINS:					
Thiamin (B_1)	-0.02	-0.05	-57	-60	-40
Riboflavin (B_2)	-0.13	-0.19	-81	-72	-81
Niacin (B_3)	-4.63	-5.24	-78	-82	-75
Pyridoxine (B_6)	0.27	-0.01	20	0	-23
Cyanocobalamin(B_{12}))	1.14	-1.7	-70	-63	-60
LIPIDS: **Saturated fatty acids (SFA)**	-1.08	-1.18	-62.87	-61.06	-40.25
14:0	-0.3	-0.32	-35	-54	-22
16:0	-2.53	-2.6	-61	-61	-43
18:0	-1.52	-1.82	-76	-6	-43
20:0	0.02	0.02	1	2	3
Monounsaturated fatty acids(MUFA)	-3.12	-2.8	-68.79	-3.32	-55.00
16:1	-0.44	-0.43	-69	-75	-63
18:1	-4.53	-7.83	-69	-70	-54
Polyunsaturated fatty acids (PUFA)	0.33	0.33			
18:2	-0.97	-0.97	-97	-79	-72
Cholesterol	-9.2	-15.3	-27	-14	-1

Data from current study (Table 4)

Difference: Calculated on the difference between the values of the current study (Table 4) and that of the 1999 MRC food composition tables (Sayed, Frans & Schönfeldt, 1999)

\- Indicates that the current study has **less** of the particular nutrient than the MRC-tables

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