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Effect of age on beef quality

by

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ABSTRACT

EFFECT OF AGE ON BEEF QUALITY

by
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A systematic description of the physical composition, eating and nutritional quality characteristics of South African beef has not been attempted before. Beef carcasses (*n* = 156) representing three age groups (A, B and C) and the full spectrum in fatness within each age group, as obtained on the commercial market were used. Each carcass side was divided into 15 retail cuts. To ensure that the effect of animal age (as defined in the current South African classification system) was accurately reflected, the fat content of carcasses was used as covariant in all the statistical analyses.

The physical composition (proportion of subcutaneous fat, meat and bone) was assessed and proximate analyses (percentage total moisture, fat, nitrogen and ash) were performed on the deboned tissue of each cut of the right sides of carcasses. Total fat and muscle content for each cut were subsequently calculated. The bone and meat content of the different cuts within the same carcass varied considerably. In general the relative meat content decreased and bone content increased in older animals (C-age). A large variation in compositional and chemical characteristics for the various cuts for the three age groups was observed. On average the fore and hind shins contained the lowest amount of chemical fat, followed by the fillet and thick flank.

The collagen content and solubility of muscles of electrically stimulated (500 V) left sides of beef carcasses (*n* = 41) were determined. Cuts (*n* = 61 left sides of carcasses) were cooked according to an appropriate dry (prime rib, wing rib, loin, *M. semitendinosus* in the silverside, rump, topside and fillet) or moist (*M. gluteobiceps* in the silverside, thick flank, chuck, brisket, neck, shoulder, thin flank and the hind and fore-shins) heat cooking method, at an oven temperature of 160°C, to an internal temperature of 70°C. Cooking losses were determined and shear force resistance and proximate analyses (percentages total moisture, fat, nitrogen and ash) were performed. A trained, ten-member panel, using an eight-point scale evaluated sensory quality characteristics. Tenderness, residue, collagen solubility, flavour and initial impression of juiciness of all cuts decreased significantly and cooking losses and sustained juiciness increased (although not linearly) with increasing animal age. Animal age did not have a significant effect on the collagen content of muscles. Cuts cooked using a dry heat cooking method were juicier (both initial and sustained) than those cooked using a moist heat cooking method.

Composite samples of three similar cuts from three different age groups were analysed on a double blind basis by various laboratories. The physical composition (proportion of subcutaneous fat, meat and bone) of each right side cut was assessed, while each left side cut was cooked prior to nutrient analyses. All cuts (subcutaneous fat plus meat; n = 270 for raw and n = 270 for cooked cuts) were analysed for proximate composition (moisture, protein, and fat), minerals (phosphorus, calcium, magnesium, potassium, sodium, copper, zinc, manganese and iron), water-soluble vitamins (thiamin, riboflavin, nicotinamide, pyridoxine, folic acid, cyanocobalamin, biotin and calcium pantothenate) and amino acids (including tryptophan and cystine). Lysine and iron were higher and linoleic acid lower in the C-age group animals than in A- or B-age animals for both raw and cooked cuts. The attributes that mostly discriminated between the different cuts within the same carcass were hydroxyproline, glycine and some minerals (phosphorus, potassium and magnesium). Meaningful recommendations concerning meat can now be made on valid South African data to include the full diversity of the population, i.e. the higher iron content in C-aged animals, that are probably more affordable to people most likely to suffer from iron deficiency anemia. Lean meat provides significant amounts of the dietary nutrients required in a healthy diet. The protein is of a high quality and quantity, and many essential vitamins (such as vitamin B_{12}) and minerals (such as iron) are present in sufficient quantities. People that are more concerned about the eating quality attributes and are prepared to pay a premium can also be advised accordingly.

OPSOMMING

INVLOED VAN OUDERDOM OP KWALITEIT VAN BEESVLEIS

deur

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Daar is nog nie tot op hede gepoog om die fisiese samestelling, eet- en voedingskwaliteitseienskappe van Suid Afrikaanse beesvleis sistematies te beskryf nie. Snitte (*n* = 15) van beeskarkasse (*n* = 156) soos in die kommersiële mark beskikbaar, van drie ouderdomsgroepe (A, B en C) en verteenwoordigend van die volle variasie vetheid binne elke ouderdomsgroep is ontleed. Om te verseker dat die effek van ouderdom van die dier akkuraat (soos in die huidige Suid Afrikaanse klassifikasiestelsel beskryf) weerspieël word, is chemiese vetinhoud van die karkas as kovariant in alle statistiese analises gebruik.

Die fisiese samestelling (relatiewe hoeveelhede onderhuidse vet, vleis en been) is bepaal en chemiese analiese (persentasie totale vog, vet, stikstof en as) is op die ontbeende weefsel van elke snit van die regtersye uitgevoer. Totale vet- en spierinhoud is vervolgens vir elke snit bereken. Soos verwag het die been- en spierinhoud tussen die verskillende snitte in dieselfde karkas aansienlik gevarieer. In die algemeen het die vleisinhoud afgeneem en die beeninhoud toegeneem in ouer diere (C ouderdom). 'n Groot variasie in die samestelling en chemiese inhoud vir die verskillende snitte van die drie ouderdomsgroepe is waargeneem. Die voor- en agterskenkels het die laagste hoeveelheid chemiese vet bevat, gevolg deur die filet en diklies.

Totale kollageeninhoud en -oplosbaarheid van spiere van elektries gestimuleerde (500 V) beeskarkasse (*n* = 41) is bepaal. Snitte (*n* = 61 karkasse) is volgens 'n geskikte droë- (primarib, voorrib, lende, *M. semitendinosus* in die dy, kruis, binneboud en filet) of klamhittegaarmaakmetode (*M. gluteobiceps* in die dy, diklies, dikrib, nek, skouer, dunlies en voor- en agterskenkels) by 'n oondtemperatuur van 160°C, tot 'n interne temperatuur van

70°C gaargemaak. Gaarmaakverliese, snyweerstand en chemiese analiese (percentasie totale vog, vet, stikstof en as) is bepaal. Sintuiglike kwaliteitseienskappe is deur 'n opgeleide paneel bestaande uit tien lede, met 'n agtpuntskaal uitgevoer. Sagtheid, residu, kollageenoplosbaarheid, geur en inisiële indruk van sappigheid van alle snitte het betekenisvol (alhoewel nie-liniêr) afgeneem en gaarmaakverliese en voortgesette sappigheid het verhoog met toenemende ouderdom. Ouderdom van die dier het nie 'n betekenisvolle effek op die kollageeninhoud van spiere gehad nie. Snitte wat volgens 'n droëhittegaarmaakmetode voorberei is, was meer sappig (inisiële en voortgesette) as dié wat volgens 'n klamhittegaarmaakmetode voorberei is.

Saamgestelde monsters van die ooreenstemmende snitte van elke ouderdomsgroep, is op 'n dubbelblinde basis deur verskillende laboratoriums ontleed. Die fisiese samestelling (relatiewe hoeveelhede onderhuidse vet, vleis en been) van elke regterkantste snit is bepaal, terwyl elke linkerkantste snit gaargemaak is voor voedingswaarde analises. Die volgende bepalings is op alle snitte (onderhuidese vet en vleis, $n = 270$ vir rou en $n = 270$ vir gaar) uitgevoer: chemiese analiese (% totale vog, vet en stikstof), minerale (fosfor, kalsium, magnesium, kalium, natrium, koper, sink, mangaan en yster), water-oplosbare vitamienes (tiamien, riboflavien, nikotienamied, piridoksien, foliensuur, cyanokobalamien, biotien en kalsiumpantonaat) en aminosure (insluitend triptofaan en sistien). Lisien en yster was hoër en linoleïensuur laer in C ouderdom diere as in A of B vir beide rou- en gaarsnitte. Die eienskappe wat die meeste tussen die verskillende snitte in dieselfde karkas onderskei het was hidroksieprolien, glisien en sommige minerale (fosfor, kaluim en magnesium).

Sinvolle aanbevelings kan nou op geldige Suid Afrikaanse data gedoen word vir die totale verskeidenheid van die Suid Afrikaanse bevolking, bv. die C ouderdom diere met 'n hoër ysterinhoud is meer bekostigbaar vir persone wat aan ystertekort ly. Maervleis voorsien betekenisvolle hoeveelhede voedingstowwe wat in 'n gesonde dieet benodig word. Die proteïne is van 'n hoë kwaliteit en kwantiteit, asook baie van die essensiële vitamienes en minerale (soos yster) is in genoegsame hoeveelhede teenwoordig. Persone wat meer bekommerd is oor die eetkwaliteitseienskappe en wat daarvoor 'n premium sal betaal, kan ook van advies voorsien word.

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Presentation of the Dissertation

STRUCTURE OF THE DISSERTATION

The dissertation is presented mainly in the form of articles and it will be presented in the following chapters:

CHAPTER 2:	**Introduction and Statement of Problem**
CHAPTER 3:	**Effect of Age on Carcass and Cut Composition of South African Beef Carcasses**
CHAPTER 4:	**Effect of Age and Cuts on Tenderness of South African Beef**
CHAPTER 5:	**Effect of Age and Cuts on Cooking Loss, Juiciness and Flavour of South African Beef**
CHAPTER 6:	**Effect of Age and Cut on the Nutritional Content of South African Beef**
CHAPTER 7:	**Conclusions and Recommendations**

The format deviates from the traditional format used for dissertations and some explanatory comments about the format and additional information not contained in chapter 2 to chapter 7 are made. The style and layout as prescribed by the Journal of Meat Science were used in this dissertation.

LITERATURE REVIEW

The relevant literature is included in each article. A literature review covering the relationship between age and carcass and cut composition; between age and tenderness of cuts; between age and cooking loss, juiciness and flavour of cuts; and between age and nutritional composition of carcass cuts of beef is not presented as a separate chapter.

MATERIALS AND METHODS

The beef carcasses were obtained on the commercial market by qualified classifiers. They had a mass range from 190 kg to 240 kg.

No specific genotype was chosen, owing to the fact that carcasses had to be representative of the market and that the South African classification system is based on age and carcass fatness regardless of genotype. In the present study only steers and heifers were selected due to the small proportion of bull carcasses presently on the market in South Africa and this can lead to a skewed distribution. The three age groups were 0 (no permanent incisors) or < 793,0 ± 6,4 days, 2 (permanent incisors) or between > 793,0 ± 6,4 days and < 1 001,0 ± 8,6 days and 8 tooth > 1 462,0 ± 10,5 days. Six fatness groups are identified for each age group. The six fat codes are:

- Fat code 1 = very lean (< 1 mm fat thickness measured between the 10th and 11th ribs, 50 mm from the median line of the cold, unquartered carcass);
- Fat code 2 = lean (1 – 3 mm fat thickness);
- Fat code 3 = medium (3,1 – 5 mm fat thickness);
- Fat code 4 = fat (5,1 – 7 mm fat thickness);
- Fat code 5 = moderately overfat (7,1 – 10 mm fat thickness);
- Fat code 6 = excessively overfat (> 10 mm fat thickness).

The carcasses were electrically stimulated (500 V) within 10 minutes of stunning, dressed, halved, chilled overnight at between 0°C and 5°C labelled and transported to the ARC-ANPI in a refrigerated truck.

Due to the fact that carcass fatness influences lean yield, carcasses representing the full fatness spectrum (of all 6 fat classes) within each age group were selected. Firstly, to ensure that visually assessed carcasses were representatively selected for the various fatness levels, it was decided to in the first instance determine the percentage chemical fat in each prime rib cut. Secondly, fat thickness of each carcass (between the 10th and 11th thoracic vertebrae, 5 cm from the midline of the carcass) was measured. Thirdly, the subcutaneous fat content of both the prime rib cut and the total carcass was determined. These values were then checked against the norm for each fatness level and thus resulted in the correct classification within each fatness level of the 156 carcasses.

Each of the 156 right and left sides of beef was subdivided into 15 primal (wholesale) cuts (including the fillet) prior to analyses. Physical dissections, proximate and nutrient analyses of raw meat were performed on the right sides (Table 1.1). Forty-one of the left beef sides were used for total collagen content and solubility determinations. Sixty-one left sides were used for sensory analysis and shear force resistance measurements. The 54 remaining left sides of beef were cooked prior to analyses of nutrient content.

In all analyses, standard methods were used as described in the articles, except for the sensory analyses and therefore the evaluation form with descriptors is included in Appendix A.

STATISTICAL ANALYSES

The statistical procedures used to establish the effect of age and cut on carcass composition, tenderness, juiciness, flavour and nutritional content is described below. In order to establish which of the large sets of correlated variates were the most important in discriminating between the age groups (A, B and C) and/or the 15 cuts, canonical variate analysis (CVA) (GENSTAT 5, 1996), also known as linear discriminant analysis, was used. Multivariate techniques, such as principal component analysis (PCA) are used to reduce a large set of variates into a smaller set, which explains most of the variation in the entire data set.

TABLE 1.1
Experimental Design for Evaluation of Characteristics of Beef Carcasses

Measurement	*N*	**Age group**					
		A		B		C	
		RS	**LS**	**RS**	**LS**	**RS**	**LS**
Physical dissection	156	✓ raw		✓ raw		✓ raw	
Proximate analyses	156	✓ raw		✓ raw		✓ raw	
Sensory analyses:	61						
Cooking losses			✓ cooked		✓ cooked		✓ cooked
Tenderness			✓ cooked		✓ cooked		✓ cooked
Juiciness			✓ cooked		✓ cooked		✓ cooked
Flavour			✓ cooked		✓ cooked		✓ cooked
Shear force resistance			✓ cooked		✓ cooked		✓ cooked
Proximate analyses			✓ cooked		✓ cooked		✓ cooked
Collagen analyses	41		✓ raw		✓ raw		✓ raw
Nutrient analyses	54	✓ raw	✓ cooked	✓ raw	✓ cooked	✓ raw	✓ cooked

PCA (GENSTAT 5, 1996) was performed on all the different variates for each of the 15 cuts, but will not be presented due to limited space. Through the PCA it was identified that fatness of the carcass was one of the most important gradients or factors identified in this multivariate data space (data matrix) and for that reason was used as covariant in the ANOVA. PCA is suitable when one is interested in the groupings of individuals. However, as definite groupings were observed in this data set, CVA was rather applied. The variability in this large number of variates was firstly reduced to a smaller set of variates, which accounted for most of the variability. If there was a strong grouping or trend in the data set, usually only a few of the important variates which influence the new variate, called canonical variates (CV), were obtained. A plot of the mean scores of each group was then obtained. This plot is a visual and easily understandable graphical representation of the similarity or groupings of the original age and/or cut groups. Furthermore, by correlating the scores with the original variates, the most important variates discriminating between the new groups were identified.

As only the directions of the main variability in the data matrix are paid attention to in the CVA, the more subtle sources of variation were investigated by ANOVA. A correlation matrix was constructed to test for correlation between the different variables. To ensure that the effect of animal age was determined and not the effect of fatness of the carcass, the percentage chemical fat of the carcass was used as covariant (X), both as natural X and X^2 in a PROC GLM (SAS, 1996) procedure. The percentage fat was determined by proximate analyses for the 15 wholesale cuts and calculated for the carcass according to the relative mass of each cut. In searching for the most simplistic model the covariant was removed from the model if not significant (very generously at $p \geq 0{,}15$) starting with X^2 and continuing with X. Separation of the mean scores for interaction of the different variables for the various cuts for the three age groups was achieved by the application of Tukey's method (SAS, 1996).

Additional statistical techniques were used for specific analyses and are discussed in more detail where applicable in the appropriate articles.

RESULTS

The results of the CVA are presented as plots and in some cases, tables, and are then discussed. The results of the ANOVA are presented in tables and discussed, with the exception of the 51 tables for nutrient content of cuts. These are included in the dissertation as Appendix B. Due to a limitation on the length of articles, carcass values for each nutrient based on the contribution of each cut to the carcass were calculated, summarised and presented in the relevant article.

LIST OF REFERENCES

One reference list consisting of all the different references used in chapter 2 to chapter 6 is not included. Instead relevant references for each chapter are provided at the end of each chapter.

2

Introduction and Statement of Problem

INTRODUCTION AND MAIN AIM OF THE STUDY

Meat, its contribution to the diet and meat-health related aspects are topics of continued interest and discussion due to its prominent position in the diet of so many people. Meat is a primary dietary component and forms an important part of a balanced and varied diet (Kauffman & Breidenstein, 1983). The presence of red meat in the diet makes attainment of the recommended nutrient allowances considerably easier than would be the case if it was absent.

Red meat supplies abundant protein of high biological value. The iron and zinc contributed to the diet are significant, not only because of the quantity provided, but also because of the bioavailability of these specific nutrients in red meat. The concentration of iron, zinc and copper in meat is higher than in the diet as a whole (McNulty, 1994). Meat also makes a significant contribution to the B-vitamins required in the diet (Williams, 1987), especially vitamin B_{12} which is absent from plant foods. Added to this is the well-recognised taste appeal and variety made possible by the inclusion of red meat in the diet (Breidenstein, 1988). The nutrient density of meat is an index of nutritional quality (Hansen, 1979). In other words, this is the quantity of nutrients relative to energy content, and it means that red meat fills a higher proportion of the requirements for those nutrients than the energy needs. This makes meat suitable for inclusion in any diet. Meat should therefore be evaluated in terms of its total composition and not only for single nutrients for which it is considered to be an exceptional source (Breidenstein, 1987).

The absolute and relative annual per capita consumption of red meat in South Africa and in industrialised countries abroad is steadily and consistently declining in favour of white meat as well as other non-meat proteins (International Meat Secretariat, 1996). The annual per capita consumption of red meat in South Africa declined from 39,3 kg in 1961 to 26,2 kg in 1993 to 18,7 kg in 1995 compared to poultry meat which increased over the same period from 2,4 kg to 18,8 kg. Red meat obtained from beef and veal contributed 11,3 kg to the total annual per capita red meat consumption of 18,7 kg with an average of 31,1 g compared to chicken at 52,0 g per person per day (Abstract of Agricultural Statistics, 1996). In comparison, the per capita consumption of beef has been estimated at 51g per person per day in the United States (Slover *et al.*, 1987).

Although the price difference between white and red meat is recognised as contributing to this phenomenon, another important reason is the negative health image of red meat due to the health risk associated with animal fat in the consumers diet (Richardson *et al.*, 1992). To establish whether this perception is justified, the compilation of sound scientific data regarding the nutritive value of red meat in South Africa was identified as a matter of great urgency. This research will have the advantage of contributing to the compilation of South African nutrient tables for meat.

A detailed knowledge of the composition of food is essential to understand the role of these nutrients in the diet. The fact that certain diseases are related to the inadequate or excessive consumption of certain food components, has highlighted the need for greater knowledge of the composition of specific foods (Johnson, 1987). Guidelines to the public should be based on convincing scientific evidence, regularly revised, made in terms of foods rather than nutrients, and should be positive and practical (Vorster, 1993).

Diets of individuals are usually analysed by utilising information contained in food composition tables. Food Composition Tables must not only be comprehensive and representative of available foods but are an essential tool in nutritional research, for planning and assessing in nutrition intervention studies, planning national food and nutrition policies and prescribing therapeutic and institutional diets. The validity of nutritional epidemiological studies depends on accurate food consumption and food composition data (Greenfield & Southgate, 1992). South African tables, however, contain information mainly generated in other countries. As recently as 1991 there were only 18% original South African values in the Medical Research Council Food Composition Tables (Langenhoven, 1994). These tables currently contain meat values based on the 1986 USA data. However, overseas data cannot readily be applied to the South African situation for various reasons. Concerning meat two main reasons are of importance, namely fatness of carcasses and differences in the cutting up of the carcass. Primarily, Choice beef carcasses in the USA contain an average of between 30% and 35% fat (Topel, 1986) as against the local 18% of target grade carcasses. In order to comply with the South African consumers' preferences for fatness, the fat level of the target grade (Super A) beef carcasses has changed considerably from 32% in 1949 to 18% in 1981 to 13% in 1991 (Naudé, 1994). In the USA lean meat is trimmed according to consumers' requirements. Furthermore, visible intramuscular fat or marbling, is regarded as being essential in the USA and it varies from 1,8% to 10,4 % as mean values for the marbling scores (Savell *et al.*, 1986), whereas 1% to 2% marbling is found in South African meat (Klingbiel, 1984). Such a high percentage of intramuscular fat cannot be attained to the exclusion of excessive quantities of subcutaneous and intermuscular fat. The American public has, however, been conditioned to want it, thus requiring that excess fat be cut away or trimmed. Secondly, the very real differences in the definition of joints and in dissection methods in the various countries, makes the direct application and interpretation of the American and Australian nutrient data on meat in the South African context, almost impossible (Meat Science Section, 1981).

Internationally there is also renewed interest in food composition to improve the amount, quality and availability of food composition data at national, regional and international level (Langenhoven *et al.*, 1996). The nutrient profiles of meat have recently been updated in the United States of America (USA) (USDA, 1997), Australia (Johnson, 1987) and in the United Kingdom (Chan *et al.*, 1995), thus ensuring consistency with changes in carcass characteristics, retail and food preparation practices and the provision of more data than were previously available. In the United Kingdom, previous tables were based on the composition of meat done in the early 1970's. Not only do their new tables include a wide range of cuts of beef, both raw and cooked in a variety of ways, but they also reflect the substantial changes in the composition of carcass meats since then, especially reductions in the amounts of fat both on the carcass itself and after trimming in the shop or at home, as well as the changes in cooking methods (Chan *et al.*, 1995). In the United States the meat tables have been extensively revised three times since the late 1970's. With the publication of the first Australian values for beef very real differences were found between their previous values which had been obtained from other countries and their present values (Cashel & Greenfield, 1995). Because no South African data are available and because overseas data are not applicable, it was decided to determine the nutrient composition of South African beef.

QUALITY OF MEAT

Today the consumer is the force that drives the food industry. The six components of consumers' preferences for food are quality, good taste, price, nutrition, variety and convenience (Veblen,1988). According to a recent survey of South Africans of all nationalities and ethnic groups (*n* = 1 259), the factors that they consider the most important when purchasing meat are, in descending order: taste (75%), colour of meat (48%), amount of fat (45%), price (36%), tenderness (30%), nutritional value (21%), not frozen (20%), packaging (17%), classification (15%) and preparation time (14%) (Market Research Africa, 1996).

These South African findings can be reconciled with the factors of Veblen (1988) in the sense that taste is mentioned in both cases, that quality may incorporate tenderness, amount of fat, and classification, nutrition equates to nutritional value, convenience and variety could include packaging and preparation time. According to this interpretation, quality, price and nutrition are the three important factors influencing consumer choice in South Africa. Pertaining to price, producer price for red meat in South Africa is driven by consumers' preference for leanness and the age of the animal. Consumers are prepared to pay more for lean meat and carcasses of younger animals and less for fat meat with high visible fat content and meat of older animals.

According to Hofmann (1990) one of the best known and most quoted definitions of quality as regards meat is the following: "Quality can best be defined as that which the public likes best and for which they are prepared to pay more than average prices." With this perception of today's consumers' preference for quality, beef quality has been defined as comprising four aspects of importance:

- Visual quality: Factors evaluated in classifying carcasses and/or factors that affect consumers' decisions when purchasing meat (e.g. subcutaneous fat cover, meat and fat colour).
- Eating quality: Tenderness, juiciness, odour and flavour intensity of the cooked product.
- Nutritional quality: Proportions of proteins, vitamins and minerals relative to energy density.
- Safety: Negligible risk from food-borne illness or poisoning and absence of drug, chemical, antibiotic or hormone residues (Dikeman, 1990).

According to this interpretation of quality, visual quality, eating quality expressed as tenderness, juiciness and flavour and the nutritional quality of beef are dependent on carcass quality. Safety quality can be influenced by factors not directly related to carcass quality. The South African meat classification system consists of two variables, namely age by dentition and fatness of the carcass. These two variables could independently and/or in combination affect the visual, eating and nutritional quality of beef.

Due to the dearth of information on the quality of South African beef, it was decided to do a large scale analytical study to describe beef quality comprehensively in the South African context. For this purpose, visual quality was seen as a description of the physical characteristics of the carcass and cut. Eating quality was interpreted as the tenderness, juiciness and flavour of the different cuts of the carcass as determined through the physical, chemical and sensory analyses. Nutritive quality was equated to the nutritive content as determined through the chemical and microbial analyses of raw and cooked meat from the different cuts of a carcass and the carcass as a whole.

OBJECTIVES

This lead to the formulation of the objectives for the study.

- The determination of the effect of age on the physical and chemical characteristics (carcass and cut composition) of South African beef.
- The determination of the effect of age on beef tenderness.
- The determination of the effect of age on cooking and sensory characteristics of beef cuts.
- To describe the effect of age of the animal on the nutrient content of raw and cooked South African beef cuts.

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3

Effect of Age on Carcass and Cut Composition of South African Beef Carcasses

ABSTRACT

The physical composition (proportion of subcutaneous fat, meat and bone) of 15 primal cuts from beef animals (n = 122) of three different age groups (as defined in the current South African classification system) and representing the full variation in fatness within each age group, was assessed. Furthermore, proximate analyses (percentages total moisture, fat, nitrogen and ash) were performed on the meat including the subcutaneous fat of each cut. Total fat and muscle content for each cut were then calculated.

To ensure that the effect of differences in carcass fatness over the age classes were accounted for in the analyses, percentage chemical fat of the carcass was included as a covariant in the statistical analyses. The bone and meat content of the different cuts within the same carcass varied considerably. In general the meat content decreased and bone content increased with increased age of the animal. A large variation in compositional and chemical characteristics for the various cuts for the three age groups was observed. On average the hind and fore shins contained the lowest amount of chemical fat, followed by the fillet and thick flank.

INTRODUCTION

The value of a beef carcass is principally based on the amount of saleable meat estimated to be in the carcass. Saleable meat is, however, a function of the proportion of lean meat in the carcass (Laville *et al.*, 1996). Consumer demand in most developed countries is primarily for lean beef (Jones *et al.,* 1988) with a continuously increased aversion to fat (Harrington, 1983). In order to comply with the South African consumers' preferences for leanness the average fat content of the target grade beef carcasses has changed considerably from 32% in 1949 to 18% in 1981 to 13% in 1992 (Naudé, 1994). This decrease in carcass fatness is not only attributed to the fact that consumers are becoming more health conscious and are concerned about cholesterol and fat in their diet (Market Research Africa, 1996). It is also price driven, since consumers are prepared to pay the highest price for these carcasses. This of course has a direct implication for the producer to produce a carcass with maximum good quality edible tissue, i.e. maximum muscle, minimum bone and optimum fat based on consumers' preference (Strydom, 1995).

In South Africa producer price is affected by the age of the animal in an inverse relationship, which naturally affects the gross return per animal. In general feedlot animals are marketed before any permanent incisors have erupted and will therefore, in terms of the South African beef carcass classification system (Government Gazette No. 5092, 1993), be classed as A-age carcasses. Under conditions of high quality natural or planted pastures (and depending on genotype: early versus late maturing) animals are normally market-ready by the time their first pair of permanent incisors have erupted, therefore yielding mostly B-age carcasses. Although the South African beef carcass classification system defines the B-age group as comprising animals with between one and six permanent incisors, for the purpose of this study, only carcasses with one and/or two permanent incisors were used to represent this class. Carcasses of the C-age group with seven or more permanent incisors consist mainly of culled old animals.

The body tissue composition (anatomical proportions of the various tissues e.g. muscles, fat deposits and bone), and chemical (water, fat, proteins and minerals) composition of an animal change as it matures (Micol *et al.*, 1991). The rate and magnitude of change in composition of carcasses are combined functions of age, feeding regime, gender, and genotype (breed/maturity type). Slaughter mass has a large influence on carcass composition. This should coincide with the point of maturity where fat is at a desirable or optimum level. Fat is the most variable tissue in the carcass (it varies in total amount and its partitioning among various depots altar markedly throughout growth), and excess fat reduces the percentage of saleable meat (Berg & Butterfield, 1976). All these factors govern the subsequent use of the product by the end-consumer.

The differences between the size of muscles in the carcass of an animal are largely determined by the growth patterns of muscles. These differences show that, in general, muscles closely related to the skeleton are the smallest and have the lowest growth impetus (with the impetus rating of muscles being expressed relative to the rate of growth of the total carcass muscle). Some of the average impetus muscles are less closely related to the skeleton, with high impetus muscles having minimal contact with the skeleton. The anatomical position of muscles is determined by their functions at different stages of carcass development and therefore has an influence on the growth impetus (Berg & Butterfield, 1976).

In South Africa the carcass and cut composition of beef animals as obtained on the commercial market were described by Naudé (1972) on a limited number of carcasses of the A-age group. Since then consumer demand for leaner carcasses resulted in a change in the intensive production systems, feeding regimes and the use of growth promoters, directly influencing the composition of the end-product. Therefore the description of the full spectrum of carcasses in terms of composition as currently available was considered by the industry as a matter of great importance.

The South African beef carcass classification system incorporates two variables, namely age by dentition (indicating tenderness) and carcass fat cover class (indicating fatness and lean yield). In this study age by dentition was the variable used to describe the changes in the anatomical composition of an animal as it grows and develops. This has a direct influence on the value of the beef carcass based on the amount of saleable meat. Therefore a compositional description of the broad spectrum of beef carcasses on the South African market can be an important tool in guiding the middleman and retailer in price formation.

The objective of the study can therefore be summarised as the determination of the effect of age on the physical and chemical characteristics (carcass and cut composition) of South African beef (statistically analysed with percentage carcass fat content as a covariant to adjust for differences in carcass fat content).

MATERIALS AND METHODS

Source of materials

The beef carcasses (*n* = 122) used in this study had a mass range of 190 kg to 240 kg. No specific genotype was chosen, owing that carcasses had to be representative of the market and that the South African classification system is based on age and carcass fatness regardless of genotype. Priyanto *et al.* (1997) showed that at a given fat thickness, breed differences did not occur in lighter weight carcasses (those ranging from 152,6 kg to 266,8 kg). In the present study only steers and heifers were selected due to the small proportion of bull carcasses currently available on the market in South Africa and this can lead to a skew distribution. Table 3.1 gives the schematic diagram of the experimental design.

TABLE 3.1
Experimental Design for Evaluation of Physical and Chemical Characteristics of Beef Carcasses

Age group			**Total number of carcasses**
A	B	C	
41	40	41	122

The three age groups were 0 (no permanent incisors) or < 793,0 ± 6,4 days, 2 (permanent incisors) or between > 793,0 ± 6,4 days and < 1 001,0 ± 8,6 days and 8 tooth > 1 462,0 ± 10,5 days (Steenkamp, 1970). The carcasses were obtained on the commercial market (at the largest abattoir in the country) and had been classified by qualified classifiers. The carcasses were electrically stimulated (500 V) within 10 minutes of stunning, were dressed, halved, chilled overnight at between 0°C and 5°C, and were labelled and transported to the ARC-ANPI in a refrigerated truck.

Since carcass fatness influences lean yield, carcasses representing the full fatness spectrum (6 fat classes) within each age group were selected. In addition, to ensure that visually assessed carcasses were representatively selected for the various fatness levels, the following was determined:

- The percentage chemical fat in each prime rib cut.
- Fat thickness of each carcass (measured between the 10th and 11th thoracic vertebrae, 5 cm from the midline of the carcass).
- The subcutaneous fat content of both the prime rib cut and the total carcass.

These values were then checked against the norm for each fatness level and thus resulted in the correct classification of carcasses within each fatness level.

Physical carcass composition

Each right side of the beef carcass was subdivided into 15 primal (wholesale) cuts (including the fillet) according to Figure 3.1. Each cut was then accurately weighed and dissected (at 10 °C ambient temperature) into subcutaneous fat, meat (muscle plus inter- and intramuscular fat) and bone to determine its physical composition. These masses of the various tissues were then added to calculate carcass composition.

Chemical analysis

The subcutaneous fat and meat tissue obtained from each cut of the 15 samples were cubed, thoroughly mixed and then minced, first through a 5 mm and then through a 2 mm mesh plate. Proximate analyses for the determination of the percentages of total moisture (oven-dry method), fat (Soxhlet extraction with diethyl ether for 16 hours), nitrogen (Kjeldahl-method using a Büchi 430 block digester and a Büchi 322 distilatlion unit) (N *x* 6,25 = protein) and ash (by ignition at 800°C) in the tissue of each cut were done according to AOAC methods (1995). Moisture and fat content of samples were determined in triplicate and protein content was determined in duplicate. If the sum of the proximate values did not meet 100±1,5% samples were reanalysed.

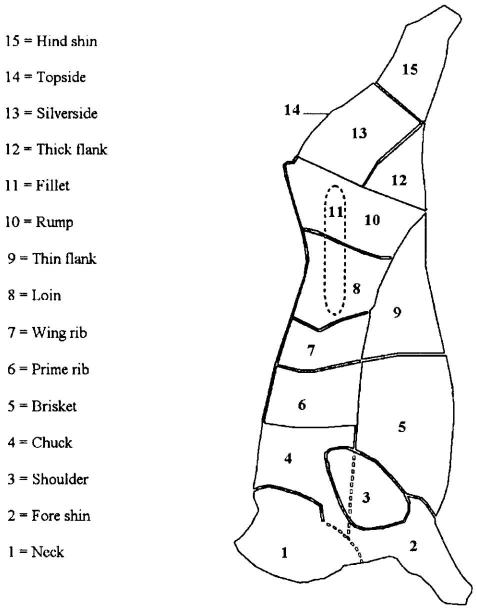

Fig. 3.1: Wholesale cuts of the carcass

Calculation of meat, fat and bone content

Carcass composition was calculated using dissection results (bone, meat and subcutaneous fat) of each of the 15 cuts of the carcass, as well as chemical composition (moisture, protein, fat and ash) of the deboned tissue of each cut. The mass of muscle in each cut was determined by adding the calculated mass of moisture, protein and ash together. The mass of ether extractable "lipid" was regarded as fat. In this way chemically determined "muscle" and "fat" were estimated and together with the dissected bone, comprised total cut content (Carroll & Conniffe, 1967). The muscle masses of each of the 15 cuts were added to calculate the carcass muscle. Similarly fat and bone masses for the carcass was determined. The subcutaneous fat as well as the meat content of the carcass was also calculated in this way.

STATISTICAL ANALYSIS

In order to establish which of the large set of correlated variates were the most important in discriminating between the age groups (A, B and C) and/or the 15 cuts, canonical variate analysis (CVA) (GENSTAT 5, 1996), also known as linear discriminant analysis, was used. Multivariate techniques, such as principal component analysis (PCA) were used to reduce a large set of variates into a smaller set, which explains most of the variation in the entire data set. PCA (GENSTAT 5, 1996) was performed on all the different variates for each of the 15 cuts, but will not be presented due to limited space (n = 5 carcass parameters x 15 cuts = 75 plots). PCA identified that fatness of the carcass was one of the most important gradients or factors identified in this multivariate data space (data matrix) and for that reason was used as covariant in the ANOVA analyses. PCA is suitable when one is interested in the groupings of individuals, but as definite groupings were observed in this data set, CVA was rather applied. The large number of variates was firstly reduced to a smaller set, which accounted for most of the variability in all the variates. If there was a strong grouping or trend in the data set, usually only a few of the important variates which influence the new variate, called canonical variates (CV), were obtained. A plot of the mean scores of each group is obtained. This plot is an easily understandable graphical representation of the similarities or groupings of the original age and/or cut groups. Furthermore, by correlating the scores with the original variates, the most important variates discriminating between the new groups were identified (Digby & Kempthorne, 1987). The logarithms of the variates were used to stabilise variances.

The multivariate analyses concentrate only on the main variability in the data matrix and ANOVA analyses were used to investigate the more subtle sources of variation (SAS, 1996) as proposed by Næs *et al.* (1996). To ensure that the effect of animal age was not biased by differences in carcass fatness between age groups, the percentage chemical fat of the carcass was used as covariant (X), both as natural X and X^2 in a PROC GLM (SAS, 1996) procedure. The percentage fat was determined by proximate analyses for the 15 wholesale cuts and calculated for the carcass according to the relative mass of each cut. In searching for the most simplistic model the covariant was removed from the model if not significant (very generously at $p \geq 0,15$) starting with X^2 and continuing with X. Separation of the mean scores for interaction of the different variables for the various cuts for the three age groups was achieved by the application of Tukey's method (SAS, 1996).

RESULTS AND DISCUSSION

The average percentage contribution of each cut to the carcass is presented in Table 3.2, for each age group individually as well as for the three age groups combined. The average percentage contribution of the fillet, thick flank, fore shin, loin, wing rib, brisket, shoulder and hind shin was not significantly ($p > 0,05$) affected by age of the animal. The rump of the A-age group contributed significantly ($p \leq 0,001$) less to the carcass than the B-age group, which in turn contributed significantly ($p \leq 0,001$) less to the carcass than the C-age group. The neck, topside and silverside of the A-age group contributed significantly ($p \leq 0,01$, $p \leq 0,05$ and $p \leq 0,05$ respectively) more to the carcass than those of the C-age group. The prime rib of the A-age group contributed significantly ($p \leq 0,001$) more to the carcass than the B- and C-age groups. The chuck of the A- and B-age groups contributed significantly ($p \leq 0,001$) less to the carcass than the C-age group. The thin flank of the A- and B-age groups contributed significantly ($p \leq 0,01$ respectively) more to the carcass than those of the C-age group. These differences between the cuts in the carcass are largely determined by the different growth patterns of muscles in the carcass (Berg & Butterfield, 1976).

Effect of age on carcass and cut characteristics

According to the canonical variate analyses results, the first canonical variate (CV1) alone accounted for 95,4% of the total variation in the data with a latent root of 0,0154 (should be >1), therefore the results cannot be regarded as significant. The main characteristic that discriminated between the carcass composition for the three age groups in CV1 (horisontal) were the chemically determined fat ($r = 0,847$) as this correlated the strongest with the CV1 scores. Physically determined subcutaneous fat ($r = 0,668$) discriminated mainly between the three age groups in the CV2 (vertical axis). The CV mean scores are presented in Figure 3.2.

For the analysis of variance (ANOVA), the average chemically determined fat content of the carcass was used as covariant in the PROC GLM procedure to adjust for differences between fat content of carcasses. The average used was 15,45% with a minimum of 6,79% and a maximum of 29,75%. The other attributes measured for this data set were:

- subcutaneous fat (%) of the carcass: mean = 5,60;

- meat (%) of the carcass: mean = 76,42;
- bone (%) of the carcass: mean = 17,59;
- muscle (%) in the carcass: mean = 67,54.

Note that subcutaneous fat + meat + bone = 100 and chemically determined fat + muscle + bone = 100, due to the influence of the covariant this is ± 100.

TABLE 3.2
Average Percentage Contribution of Each Cut to the Carcass

Cut	All Ages	p-Value	A-age	B-age	C-age
Shoulder	11,20	0,2065	11,15	11,11	11,33
Hind Shin	2,51	0,0993	2,59	2,51	2,44
Neck	7,96	0,0066	$8,27^{a}$	$7,95^{ab}$	$7,65^{b}$
Prime Rib	3,42	0,0001	$3,62^{a}$	$3,36^{b}$	$3,27^{b}$
Chuck	9,92	0,0007	$9,55^{a}$	$9,82^{a}$	$10,40^{b}$
Brisket	13,05	0,2661	12,81	13,16	13,20
Thin Flank	8,19	0,0123	$8,47^{a}$	$8,31^{a}$	$7,80^{b}$
Wing Rib	2,78	0,3217	2,83	2,81	2,72
Loin	4,49	0,3220	4,41	4,50	4,56
Rump	7,42	0,0001	$7,01^{a}$	$7,37^{b}$	$7,91^{c}$
Topside	9,54	0,0152	$9,76^{a}$	$9,50^{ab}$	$9,35^{b}$
Silverside	9,43	0,0531	$9,59^{a}$	$9,41^{ab}$	$9,26^{b}$
Thick Flank	5,14	0,8269	5,12	5,18	5,13
Fillet	2,18	0,9580	2,19	2,18	2,17
Fore Shin	2,78	0,3272	2,73	2,82	2,80

^{abc} Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

According to the physical dissection results, the subcutaneous fat content of cuts at an equal carcass fat content, increased significantly with age in four of the 15 cuts studied. The loin ($p \leq 0,05$), wing rib ($p \leq 0,001$), rump ($p \leq 0,001$) and fore shin ($p \leq 0,05$) of A- (0 tooth) and B-group (2 tooth) had significantly less subcutaneous fat compared to the C-age group (Table 3.3).

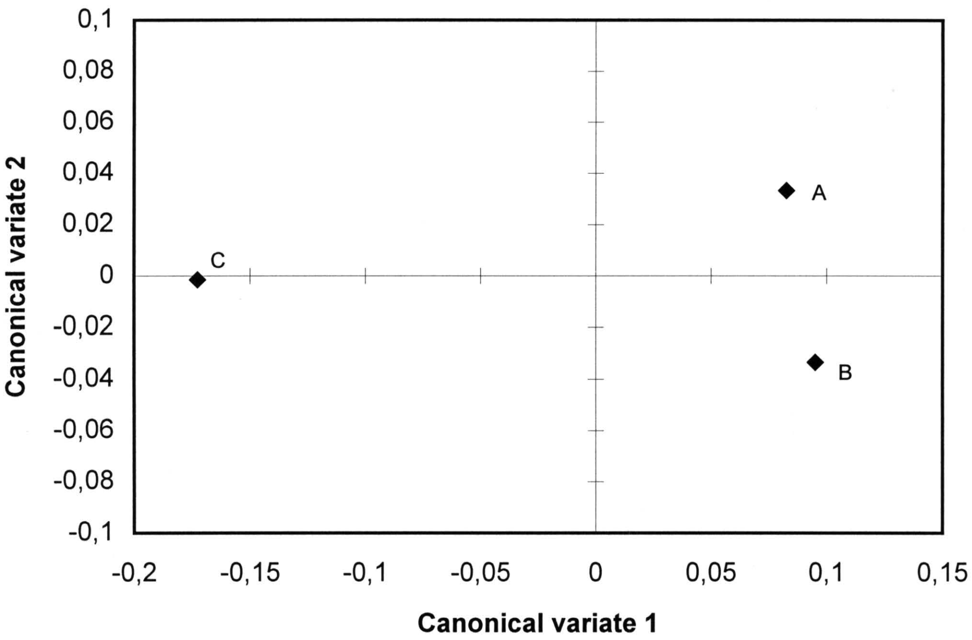

Fig. 3.2: Plot of CV mean scores of Age groups[1]

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[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

The physically determined meat content at an equal carcass fat content, decreased significantly with age in seven of the 15 cuts, as well as in the calculated carcass meat content. The prime rib, loin, wing rib, rump, brisket and shoulder of A- (0 tooth) and B-age (2 tooth) groups had significantly ($p \leq 0{,}01$) more meat than that from the C-age group (Table 3.4). The neck of the A-age group (0 tooth) had significantly ($p \leq 0{,}001$) more meat compared to that from the B-age group which, in turn, had significantly ($p \leq 0{,}001$) more meat than cuts obtained from the C-age group.

The bone content increased significantly with age (A- and B- versus C-age groups) in eight of the 15 cuts at an equal carcass fat content, as well as in the calculated carcass bone content. The neck and thin flank of the A-age group (0 tooth) had significantly ($p \leq 0{,}001$) less bone compared to that from the B-age group which, in turn, had significantly ($p \leq 0{,}001$) less bone than cuts obtained from the C-age group (Table 3.5). The prime rib, loin, wing rib, topside, brisket and shoulder of A- (0 tooth) and B- (2 tooth) age groups had significantly ($p \leq 0{,}01$) less bone than those from the C-age group.

TABLE 3.3
Least Square Mean Values (± Standard Error Of Mean) of Physically Determined Subcutaneous Fat (%) for Beef Cuts Obtained from Three Age Groups (*n* = 18) (Fat of the Carcass Covariant = 15,45%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1. Prime rib	67	0,0001	0,0001		0,9517	6,25	0,261	6,25	0,268	6,35	0,262
2. Loin	72	0,0001	0,0001		0,0187	$8,16^a$	0,348	$8,50^a$	0,352	$9,51^b$	0,345
3. Wing rib	63	0,0001	0,0001		0,0002	$9,03^a$	0,410	$8,72^a$	0,421	$11,04^b$	0,412
4. Rump	58	0,0001	0,0001		0,0008	$6,97^a$	0,403	$6,65^a$	0,414	$8,74^b$	0,404
5. Topside	52	0,0001	0,0001		0,5631	8,30	0,350	7,99	0,359	7,77	0,351
6. Fillet					-	-		-		-	
7. Silverside	44	0,0001	0,0001		0,0991	6,06	0,385	6,11	0,400	7,12	0,386
8. Thick flank	17	0,0002	0,0168	0,0865	0,1590	6,18	0,332	5,49	0,341	6,37	0,333
9. Chuck	58	0,0001	0,9946	0,0333	0,9202	1,33	0,095	1,28	0,098	1,28	0,096
10. Brisket	43	0,0001	0,0001		0,2676	5,36	0,332	4,84	0,341	5,61	0,333
11. Neck	24	0,0001	0,0085	0,0872	0,6420	3,41	0,334	3,71	0,343	3,26	0,336
12. Shoulder	52	0,0001	0,0001		0,8153	4,27	0,264	4,29	0,271	4,49	0,265
13. Thin flank	49	0,0001	0,0001		0,2822	21,07	0,804	20,64	0,824	19,31	0,806
14. Fore shin	18	0,0001	0,0001		0,0281	$0,86^a$	0,117	$0,58^a$	0,120	$1,03^b$	0,117
15. Hind shin	9	0,0246	0,0477	0,0236	0,1066	2,11	0,240	1,40	0,249	1,98	0,244
16. Carcass*	78	0,0001	0,0001		0,4384	6,54	0,190	6,32	0,192	6,66	0,188

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

abc Means in a row with different superscripts differ significantly ($p \leq 0,05$)

Age of the animal had a significant effect on the chemical composition of the various cuts analysed with carcass fat content as a covariant. According to the results, four of the 15 cuts increased and three decreased in fat content with age (Table 3.6). The rump and silverside of the A- and B-age groups contained significantly ($p \leq 0,01$) less fat compared to those from the C-age group. The prime rib of A-age group (0 tooth) had significantly ($p \leq 0,05$) less fat than the B- and C-age groups. The wing rib of the A-age group contained significantly ($p \leq 0,001$) less fat than that from B-age group (2 tooth), which in turn contained significantly ($p \leq 0,001$) less fat than that from the C-age group (8 tooth). The neck of the A- and B-age groups contained significantly ($p \leq 0,01$) more fat compared to those from the C-age group. The thick and thin flank of A-age group (0 tooth) had significantly ($p \leq 0,05$) more fat than the B- and C-age groups.

TABLE 3.4

Least Square Mean Values (± Standard Error of Mean) of Physically Determined Meat (%) for Beef Cuts Obtained from Three Age Groups (*n* = 18) (Fat of the Carcass Covariant 15,45%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1. Prime rib	19	0,0001	0,1142	0,0307	0,0012	$76{,}88^a$	0,459	$76{,}23^a$	0,471	$74{,}50^b$	0,461
2. Loin	28	0,0001	0,0001		0,0001	$73{,}69^a$	0,597	$72{,}54^a$	0,605	$70{,}09^b$	0,592
3. Wing rib	28	0,0001	0,0001		0,0001	$72{,}43^a$	0,556	$73{,}12^a$	0,570	$69{,}04^b$	0,558
4. Rump	35	0,0001	0,0001		0,0002	$75{,}33^a$	0,434	$75{,}84^a$	0,446	$73{,}31^b$	0,436
5. Topside	43	0,0001	0,0001		0,2964	84,55	0,367	84,85	0,377	84,03	0,368
6. Fillet	7	0,0677	0,0249	0,0471	0,3402	99,73	0,152	99,99	0,156	100,00	0,153
7. Silverside	44	0,0001	0,0001		0,1156	93,90	0,385	93,86	0,400	92,88	0,386
8. Thick flank	10	0,0145	0,0314	0,0876	0,2689	90,88	0,345	91,48	0,354	90,71	0,346
9. Chuck	1	0,9383			0,9383	83,34	0,307	83,47	0,322	83,32	0,318
10. Brisket	13	0,0022	0,0839	0,0824	0,0008	$76{,}33^a$	0,442	$76{,}29^a$	0,453	$74{,}19^b$	0,444
11. Neck	25	0,0001			0,0001	$82{,}40^a$	0,429	$80{,}55^b$	0,450	$78{,}42^c$	0,444
12. Shoulder	37	0,0001	0,0001		0,0066	$87{,}51^a$	0,289	$87{,}20^a$	0,296	$86{,}23^b$	0,290
13. Thin flank	27	0,0001	0,0001		0,5379	75,78	1,239	73,92	1,271	75,47	1,243
14. Fore shin	9	0,0217	0,0215	0,0308	0,0501	44,84	0,405	46,26	0,415	45,38	0,406
15. Hind shin	12	0,0048	0,0022	0,0090	0,8368	34,63	0,733	35,22	0,761	35,11	0,744
16. Carcass*	56	0,0001	0,6821	0,1256	0,0001	$80{,}34^a$	0,211	$80{,}08^a$	0,214	$78{,}79^b$	0,210

[1] p-values are of the full model, if not significant ($p \geq 0{,}15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0{,}05$)

The chemically determined and then calculated muscle content decreased significantly with age in six of the 15 cuts analysed with carcass fat content as a covariant. The prime rib of the A- (0 tooth) had significantly ($p \leq 0{,}01$) more muscle than the B-age group, that in turn had significantly ($p \leq 0{,}01$) more muscle than the C-age group (Table 3.7). The loin, wing rib, rump and silverside of A- (0 tooth) and B- (2 tooth) age groups contained significantly ($p \leq 0{,}01$) more muscle than that from the C-age group (8 tooth). The muscle content in the neck of A- (0 tooth) was significantly ($p \leq 0{,}05$) more than the C-age group. The muscle content in the thick flank of A- (0 tooth) was significantly ($p \leq 0{,}05$) less than the B-and C-age groups.

TABLE 3.5
Least Square Mean Values (± Standard Error Of Mean) of Physically Determined Bone (%) for Beef Cuts Obtained from Three Age Groups ($n = 18$) (Fat of the Carcass Covariant = 15,45%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1. Prime rib	39	0,0001	0,0001	0,0014	0,0002	16,86^{a}	0,392	16,52^{a}	0,402	19,19^{b}	0,394
2. Loin	34	0,0001	0,0104	0,1267	0,0044	18,14^{a}	0,474	19,22^{a}	0,480	20,40^{b}	0,470
3. Wing rib	39	0,0001	0,0021	0,0604	0,0108	18,53^{a}	0,435	18,15^{a}	0,446	19,96^{b}	0,436
4. Rump	30	0,0001	0,0029	0,0523	0,5184	17,69	0,288	17,49	0,296	17,97	0,290
5. Topside	24	0,0001	0,0065		0,0001	7,16^{a}	0,167	7,16^{a}	0,171	8,20^{b}	0,167
6. Fillet	7	0,0677	0,0249	0,0471	0,3402	0,07	0,039	0,00	0,040	0,00	0,039
7. Silverside	4	0,0944			0,0944	0,03	0,014	0,04	0,014	0,00	0,014
8. Thick flank	9	0,0118	0,0010		0,8280	2,95	0,129	3,03	0,132	2,92	0,129
9. Chuck	16	0,0002	0,0001		0,9560	15,40	0,310	15,28	0,318	15,39	0,311
10. Brisket	51	0,0001	0,0001	0,0021	0,0004	18,31^{a}	0,341	18,87^{a}	0,350	20,22^{b}	0,342
11. Neck	51	0,0001	0,0189	0,1429	0,0001	14,13^{a}	0,335	15,90^{b}	0,344	18,32^{c}	0,336
12. Shoulder	47	0,0001	0,0002	0,0038	0,0001	8,22^{a}	0,107	8,51^{a}	0,110	9,30^{b}	0,108
13. Thin flank	53	0,0001	0,0001		0,0001	3,17^{a}	0,148	3,92^{b}	0,152	5,18^{c}	0,149
14. Fore shin	11	0,0081	0,0110	0,0291	0,1363	54,30	0,401	53,16	0,412	53,59	0,403
15. Hind shin	12	0,0039	0,0100	0,0467	0,8869	63,26	0,694	63,39	0,721	62,91	0,705
16. Carcass*	61	0,0001	0,0001	0,0038	0,0001	13,23^{a}	0,139	13,60^{a}	0,141	14,53^{b}	0,138

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

The effect of age on the physically separated carcass tissues can be summarised as an increase in bone content from A- and B-age group to C-age group, with a decrease in meat content with age at an equal carcass fat content. This is a result of negative muscle growth between B- and C-ages. The effect of age on the chemical composition of the carcass at an equal carcass fat content can be summarised as a significant increase in fat content with age in four of the 15 cuts and a decrease in three of the cuts. The chemically determined muscle content decreased significantly with age in six of the 15 cuts and increased in one of the cuts analysed. Maturity of the animal is usually reflected in the proportion of fat, accompanied by a decrease in the proportion of water and protein in the body. The chemical component in the carcass showing the greatest variability was fat (Berg & Butterfield, 1976). However, since the comparisons in this study were made at an equal carcass fat content, these differences in chemical composition with age in the cuts are mostly explained by the normal growth patterns within the carcass with age. A contributing factor to these differences could be due to the difference in feeding regime between the three age groups.

TABLE 3.6
Least Square Mean Values (± Standard Errors) of Chemically Determined Fat (%) for Beef Cuts Obtained from Three Age Groups (*n* = 18) (Fat of the Carcass Covariant 15,45%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1. Prime rib	83	0,0001	0,0001		0,0109	$18,60^a$	0,443	$19,88^b$	0,455	$20,48^b$	0,445
2. Loin	85	0,0001	0,0001		0,4502	16,84	0,394	16,50	0,394	17,21	0,395
3. Wing rib	85	0,0001	0,0001	0,1076	0,0004	$18,19^a$	0,454	$19,49^b$	0,466	$20,85^c$	0,456
4. Rump	85	0,0001	0,0001		0,0001	$14,89^a$	0,318	$15,07^a$	0,327	$15,70^b$	0,319
5. Topside	70	0,0001	0,0001		0,4030	12,93	0,355	12,28	0,364	12,42	0,356
6. Fillet	15	0,0002	0,0001		0,1828	8,43	0,406	8,67	0,468	7,52	0,457
7. Silverside	75	0,0001	0,0001		0,0072	$11,49^a$	0,331	$11,33^a$	0,344	$12,72^b$	0,332
8. Thick flank	47	0,0001	0,0001		0,0432	$10,41^a$	0,329	$9,30^b$	0,337	$9,48^b$	0,330
9. Chuck	84	0,0001	0,0001		0,0886	12,63	0,282	13,23	0,289	13,50	0,283
10. Brisket	91	0,0001	0,0001	0,0149	0,2285	24,08	0,312	23,93	0,320	23,35	0,313
11. Neck	75	0,0001	0,0001		0,0001	$16,17^a$	0,390	$15,53^a$	0,400	$13,48^b$	0,391
12. Shoulder	79	0,0001	0,0001		0,8401	11,83	0,276	11,63	0,283	11,62	0,277
13. Thin flank	81	0,0001	0,0001		0,0212	$32,03^a$	0,631	$33,08^b$	0,656	$30,52^b$	0,633
14. Fore shin	48	0,0001	0,0001		0,7751	3,78	0,132	3,76	0,136	3,65	0,133
15. Hind shin	39	0,0001	0,0001		0,2819	5,52	0,236	5,04	0,242	5,07	0,236

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 3.7

Least Square Mean Values (± Standard Error of Mean) of Chemically Determined Muscle (%) for Beef Cuts Obtained from Three Age Groups (*n* = 18) (Fat of the Carcass Covariant 15,45%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1. Prime rib	68	0,0001	0,0001		0,0001	64,82^{a}	0,530	62,59^{b}	0,544	60,64^{c}	0,532
2. Loin	60	0,0001	0,0001		0,0024	65,04^{a}	0,539	64,45^{a}	0,539	62,43^{b}	0,541
3. Wing rib	65	0,0001	0,0001		0,0001	63,15^{a}	0,576	62,52^{a}	0,591	59,53^{b}	0,578
4. Rump	67	0,0001	0,3721	0,0874	0,0018	67,33^{a}	0,406	67,57^{a}	0,417	65,62^{b}	0,408
5. Topside	62	0,0001	0,0001		0,0556	79,74	0,369	80,67	0,379	79,42	0,371
6. Fillet	4	0,0687			0,0687	89,98	0,786	91,31	0,806	92,58	0,786
7. Silverside	75	0,0001	0,0940	0,1411	0,0031	88,21^{a}	0,348	88,80^{a}	0,362	87,07^{b}	0,349
8. Thick flank	41	0,0001	0,0001		0,0456	86,51^{a}	0,336	87,70^{b}	0,345	87,29^{b}	0,337
9. Chuck	58	0,0001	0,0001		0,4555	71,79	0,428	72,02	0,439	71,27	0,429
10. Brisket	73	0,0001	0,0001		0,1739	57,66	0,430	57,34	0,441	56,54	0,431
11. Neck	54	0,0001	0,6173	0,1435	0,0364	69,74^{a}	0,441	68,73^{ab}	0,453	68,13^{b}	0,443
12. Shoulder	69	0,0001	0,3617	0,0649	0,2463	79,55	0,292	79,61	0,300	78,97	0,293
13. Thin flank	78	0,0001	0,0001		0,3192	64,78	0,639	63,50	0,664	64,65	0,641
14. Fore shin	9	0,0283	0,0454	0,0291	0,0786	41,84	0,420	43,05	0,430	42,98	0,421
15. Hind shin	7	0,0773	0,0075	0,0100	0,5919	31,14	0,614	31,64	0,630	32,03	0,616

[1] p-values are of the full model, if not significant ($p \geq 0{,}15$) the covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in a row with different superscripts differ significantly ($p \leq 0{,}05$)

The discrimination between the cuts

According to the canonical variate analyses results the first two canonical variates (CV1 and CV2) accounted for 94,3% of the total variation in the data, with latent roots 66,5 and 24,7 (should be >1). The main characteristics that account for the differences in the composition of the cuts in CV1 (horizontal) were the physically determined bone (r = 0,997), the chemically determined muscle (r = -0,814) and the physically determined meat (r = -0,779) as this correlated the strongest with the CV1 scores. Figure 3.3 is a graphical representation of the CV mean scores, also given in Table 3.8. Inspection of the results (Figure 3.3) shows that, as expected, the cuts that contained little or no bone (such as the fillet, silverside and thick flank) are contrasted against the cuts containing a high bone content (such as the shins); with the associated higher meat and muscle content in the former.

The chemically determined fat (r = -0,715) and physically determined subcutaneous fat (r = -0,584) discriminated mainly between the cuts in the CV2 (vertical axis). The shins, fillet and silverside are contrasted against the brisket according to fat (chemically and physically determined) with the former being low in chemically determined and subcutaneous fat and the latter high. These differences between the various cuts are as expected and are largely due to the deposition of fat (subcutaneous, intermuscular and intramuscular) in the different cuts (Hedrick *et al.*, 1989).

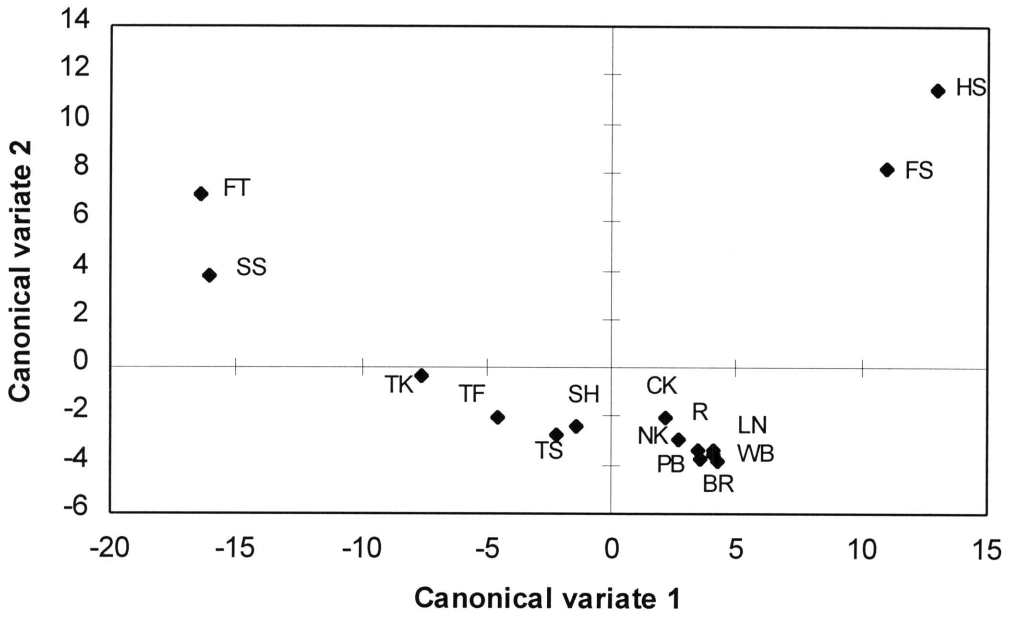

Fig. 3.3: Plot of CV mean score of Cut[1]

[1] PB – Prime rib, LN – Loin, WB – Wing rib, RP – Rump, FT – Fillet, SS – Silverside, TS – Topside, TK – Thick flank, CK – Chuck, BR – Brisket, NK – Neck, SH – Shoulder, TF – Thin flank, FS – Fore shin, HS – Hind shin

The mean scores for the compositional and chemical characteristics for the various cuts for the three age groups are presented in Table 3.9. A large variation in percentage chemically determined fat was observed, where the thin flank (33,16%), brisket (29,24%), wing rib (23,89%) and prime rib (23,77%) in descending order contained the highest amount of chemical fat and the fore shin, fillet and thick flank (7,99%, 8,23% and 10,30%, respectively) the least.

TABLE 3.8
Canonical Variate Mean Scores of Various Cuts

CUT	CV1	CV2
Fillet	-16,396	7,123
Silverside	-16,096	3,796
Thick Flank	-7,601	-0,305
Thin Flank	-4,569	-2,075
Topside	-2,229	-2,745
Shoulder	-1,437	-2,443
Chuck	2,156	-2,056
Neck	2,655	-2,937
Rump	3,442	-3,441
Prime Rib	3,608	-3,727
Loin	4,048	-3,366
Wing Rib	4,068	-3,588
Brisket	4,253	-3,829
Fore Shin	10,955	8,139
Hind Shin	13,005	11,440

The thin flank, wing rib and loin contained the highest amount of separable subcutaneous fat and the fillet and fore shin the least. The fillet, silverside and thick flank contained the highest percentages physically dissected meat and chemically determined muscle, with the lowest percentage bone in the carcass. This inverse relationship between proportions of muscle, fat and bone is well known (Hedrick *et al.*, 1989).

TABLE 3.9
Ranking of Cuts According to Compositional and Chemical Characteristics

Ranking Order	Moisture	Protein	Fat	Subcutaneous Fat	Muscle	Bone	Meat
1	Fillet	Fore Shin	Thin Flank	Thin Flank	Fillet	Hind Shin	Fillet
	70,40	21,71	33,16	20,34	99,91	63,23	99,98
2	Fore Shin	Hind Shin	Brisket	Wing Rib	Silverside	Fore Shin	Silverside
	69,10	20,62	29,24	9,57	93,60	53,68	99,97
3	Thick Flank	Silverside	Wing Rib	Loin	Thick Flank	Loin	Thick Flank
	68,47	20,53	23,89	8,69	91,00	19,25	97,04
4	Silverside	Thick Flank	Prime Rib	Topside	Shoulder	Brisket	Thin Flank
	66,48	20,38	23,71	7,99	86,98	19,15	95,91
5	Shoulder	Fillet	Loin	Rump	Topside	Wing Rib	Topside
	65,99	20,25	20,67	7,44	84,51	18,88	92,49
6	Topside	Topside	Rump	Carcass	Chuck	Prime Rib	Shoulder
	65,23	20,20	18,84	6,49	83,35	17,85	91,31
7	Chuck	Shoulder	Carcass	Silverside	Neck	Rump	Carcass
	64,45	20,03	18,50	6,38	80,47	17,73	86,22
8	Hind Shin	Chuck	Neck	Prime Rib	Carcass	Neck	Chuck
	64,44	19,23	17,85	6,24	79,73	16,10	84,73
9	Neck	Neck	Chuck	Thick Flank	Prime Rib	Chuck	Neck
	62,13	19,11	15,43	6,04	75,92	15,27	83,90
10	Rump	Carcass	Hind Shin	Brisket	Thin Flank	Carcass	Rump
	61,65	19,04	13,98	5,29	75,58	13,79	82,27
11	Carcass	Loin	Topside	Shoulder	Brisket	Shoulder	Prime Rib
	61,32	18,94	13,55	4,33	75,57	8,69	82,16
12	Loin	Rump	Shoulder	Neck	Rump	Topside	Wing rib
	59,50	18,68	12,79	3,43	74,84	7,51	81,12
13	Prime Rib	Wing Rib	Silverside	Hind Shin	Loin	Thin Flank	Brisket
	57,65	18,31	11,86	1,77	72,06	4,09	80,85
14	Wing Rib	Prime Rib	Thick Flank	Chuck	Wing Rib	Thick Flank	Loin
	57,05	17,99	10,03	1,38	71,55	2,96	80,75
15	Brisket	Thin Flank	Fillet	Fore Shin	Fore Shin	Silverside	Fore Shin
	53,18	16,83	8,23	0,82	45,51	0,03	46,32
16	Thin Flank	Brisket	Fore Shin	Fillet	Hind Shin	Fillet	Hind Shin
	49,43	16,81	7,99	0,07	35,00	0,02	36,77

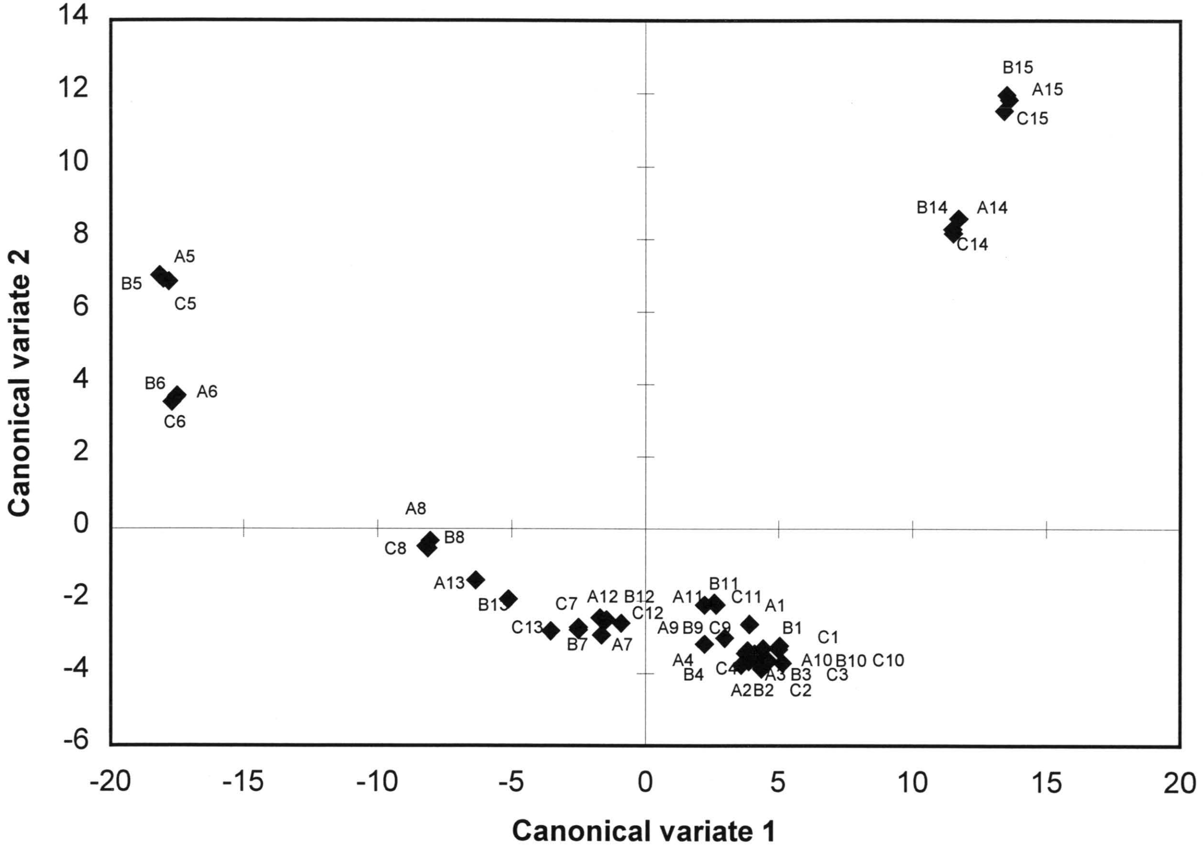

Fig. 3.4: Plot of CV mean score of Age groups[1] by Cuts[2]

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[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

[2] 1 - Prime rib (PB), 2 - Loin (LN), 3 - Wing rib (WB), 4 – Rump (RP), 5 – Fillet (FT), 6 – Silverside (SS), 7 – Topside (TS), 8 - Thick flank (TK), 9 – Chuck (CK), 10 – Brisket (BR), 11 – Neck (NK), 12 – Shoulder (SH), 13 - Thin flank (TF), 14 - Fore shin (FS), 15 - Hind shin (HS)

The discrimination between age by cut

The first two canonical variates (CV1 and CV2) accounted for 94,7% of the total variation in the data, with large latent roots 79,3 and 25,0. The physically determined bone (r = 0,998), the chemically determined muscle (r = -0,799) and the physically determined meat (r = -0,764) correlated the strongest with the CV1 scores, and constitute the main characteristics that discriminate between the composition of the cuts in CV1 (horisontal). Figure 3.3 is a graphical representation of the CV mean scores, also given in Table 3.10. The chemically determined fat (r = -0,714) and physically determined subcutaneous fat (r = -0,580) discriminated mainly between the cuts in the CV2 (vertical axis). As all three age groups are neatly grouped together for each cut and the three age groups are similarly positioned as in Figure 3.4, indications are that the differences between cuts were much more discriminating than those for age and one should, therefore, refer to the discrimination by cuts.

TABLE 3.10
Canonical Variate Mean Scores of Age Groups by Various Cuts

Cut	A-Age		B-Age		C-Age	
Fillet	-17,832	6,837	-18,030	6,904	-18,177	7,010
Silverside	-17,520	3,686	-17,562	3,649	-17,721	3,509
Thick Flank	-8,135	-0,539	-8,058	-0,322	-8,220	-0,478
Thin Flank	-6,361	-1,424	-5,128	-1,950	-3,550	-2,822
Topside	-2,530	-2,799	-2,521	-2,730	-1,653	-2,934
Shoulder	-1,714	-2,451	-1,484	-2,514	-0,932	-2,605
Neck	2,205	-3,184	2,966	-3,019	3,912	-2,639
Chuck	2,572	-2,045	2,214	-2,100	2,641	-2,106
Prime Rib	3,592	-3,773	3,882	-3,669	4,615	-3,651
Rump	3,835	-3,360	3,744	-3,442	4,095	-3,478
Loin	4,095	-3,447	4,421	-3,314	5,047	-3,231
Brisket	4,356	-3,881	4,522	-3,735	5,145	-3,714
Wing Rib	4,365	-3,637	4,190	-3,665	5,005	-3,326
Fore Shin	11,695	8,572	11,474	8,284	11,496	-8,532
Hind Shin	13,594	11,838	13,498	11,966	13,409	11,533

CONCLUSIONS AND RECOMMENDATIONS

A compositional description of the broad spectrum of beef carcasses on the South African market as affected by age on the physical and chemical characteristics (carcass and cut composition) of South African beef has been compiled based on the results of this research work. Age of the animal at an equal carcass fat content affected the physically separated carcass tissues. Bone content increased with increased age, with a decrease in meat content (C-age group). The effect of age on the chemical composition of the carcass at an equal carcass fat content is described as a significant decrease in the chemically determined muscle content with age (C-age group). These findings are a result of loss of meat or muscle mass (negative muscle growth) between B- and C-ages.

A large variation in compositional and chemical characteristics for the various cuts for the three age groups was observed. The parallel between growth patterns of chemical components (water, protein, fat and ash) and those of physically separated muscle, fat and bone to establish the true relationship of results from the two methods should be further investigated, as well as the prediction of total carcass composition from a specific cut.

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4

Effect of Age and Cuts on Tenderness of South African Beef

ABSTRACT

The tenderness characteristics of primal cuts of beef of three different age groups were assessed. Muscle obtained from the 15 wholesale cuts of electrically stimulated (500 V) beef carcasses (n = 41) was used to determine total collagen content and solubility. Fifteen wholesale consumer cuts in each age group (as defined in the current South African classification system) and representing the full variation in fatness in each age group (n = 61 carcasses) were cooked according to an appropriate dry or moist heat cooking method. Tender cuts (prime rib, wing rib, loin, M. semitendinosus *in the silverside, rump, topside and fillet) were cooked using a dry-heat method. Less tender cuts (*M. gluteobiceps *in the silverside, thick flank, chuck, brisket, neck, shoulder, thin flank and the hind and fore shins) were cooked using a moist heat method in order to convert collagen to gelatine. All the cuts were cooked at an oven temperature of 160 °C, to an internal temperature of 70 °C. A trained, ten-member panel, using an eight-point scale evaluated sensory quality characteristics (tenderness and residual amount of connective tissue). Shear force resistance and proximate analyses (percentage total moisture, fat, nitrogen and ash) were also performed.*

To adjust for possible differences in carcass fatness of the different age groups, the percentage chemical fat of the carcass was used as a covariant in the statistical analyses. Tenderness, residue and collagen solubility of all cuts decreased significantly (although not linearly) with animal age, with collagen solubility the largest discriminant between the three age groups. Animal age did not have a significant effect on the collagen content *of the muscles. As expected, the tenderness characteristics of primal cuts from the same carcass varied considerably, with collagen content and shear force resistance as the largest discriminants between the 16 cuts.*

A comparison of the different muscles showed that, in order to determine carcass tenderness, the VL, SM, GB, ST and TBCL are more representative and the PM, LL, FDL, ECR and LTP less so.

INTRODUCTION

Tenderness is a primary determinant of the eating quality and acceptability of meat (Dransfield, 1994). This is easily confirmed by the positive relationship between the price of a cut of meat and its relative tenderness (Savell & Shackelford, 1992). Consumer preference studies of sensory attributes in samples of whole cuts of beef usually rate tenderness as the most important criterion, compared to flavour and juiciness (Tornberg, 1996).

Meat tenderness is evaluated by both sensory and instrumental methods. The Warner Bratzler shear method is the most widely used and yields the best correlation with sensory panel scores for tenderness. However, the results are dependent on experimental conditions and are difficult to interpret in structural terms. Since meat is eaten, tenderness evaluation by the human senses (by consumers and/or trained sensory panels) is the ultimate test (Tornberg, 1996). When sensory measurements are related to consumer preference, it is evident that texture, and especially tenderness and juiciness, have a substantial effect on meat cut preference (Chambers & Bowers, 1993). Goll *et al.* (1974) postulated that, because neither water nor lipid is intrinsically tough, it follows that neither water nor lipid contributes directly in any major way to meat tenderness and that muscle proteins are the fundamental cause of variation in meat tenderness.

Meat tenderness originates in the structural and biochemical properties of skeletal muscle fibres, especially myofibrils and intermediate filaments, and in the intramuscular connective tissue, the endomysium and the perimysium, which are composed of collagen fibrils and fibres (Takahashi, 1996). The tenderness of meat is influenced by the following variables: animal age and gender, rate of glycolysis, amount and solubility of collagen, sarcomere length, ionic strength and degradation of myofibrillar proteins by the proteinases (Koohmaraie, 1994). The results of a survey (Kingston *et al.* (1987) in Shorthose and Harris (1990)) on consumer preferences for the physical properties of beef loin and topside steaks from animals of different ages (dentition groups), fat classes, gender and breeds, indicated that consumers generally preferred electrically stimulated meat of 0 to 2 tooth animals.

Numerous researchers (Hill, 1966; Bailey, 1972; Dutson, 1974) have investigated the relationship between the age of the animal and the palatability traits of the beef. The results of these studies have consistently shown that as the age of the animal advances the beef palatability (in terms of tenderness) decreases due to decreasing amounts of heat-labile collagen. Shorthose and Harris (1990) confirmed that animal age is an important factor in determining the tenderness and acceptability of meat. Their findings showed that the mean tenderness of twelve beef muscles from animals of eight age groups (ranging from one to approximately 60 months old), decreased significantly ($p < 0,001$) with age and that the rate of toughening of these individual muscles was related to their connective tissue strength. All these carcasses were electrically stimulated or tenderstretched. However, the effects of animal age would be expected to be different, for particular muscles, in non stimulated carcasses and the extent of these differences would vary, depending on chilling conditions and differences in carcass mass.

Two separate phases of toughness are associated with increasing cooking temperature. In the first phase, there is a three- to fourfold toughening of muscle proteins (associated with denaturation of the myofibrillar structure) as the cooking temperature rises from 40°C to 50°C. Toughness doubles in the second phase (linked to collagen shrinkage, specifically the epi- and perimysium) as the cooking temperature rises to between 60°C and 75°C (Davey & Gilbert, 1974), causing compression of muscle bundles and water loss (Light *et al.*, 1985). Shrinkage of collagen, conversion of collagen to gelatine, melting of fat, changes in pH and loss of water-holding capacity occurs during heating. Chemical changes in the heat-labile compounds include the breaking of many of the myofibrils at the Z-lines and the virtual disintegration of the I-bands (Jones, 1977).

Varying degrees of expected tenderness usually dictate the cooking method for different cuts. Only inherently tender meat is normally cooked with dry heat. Meat that is inherently tough requires relatively low temperatures in the presence of moisture for several hours to obtain a reasonably tender cooked product (Ledward in Priestley, 1979). Collagen characteristics vary between muscles in a carcass, between carcasses for individual muscles, with animal age and breeds, and with cooking conditions (Harris, 1976). According to Bailey (1988), collagen (and its nature), despite being a minor component of meat plays a major role in determining the texture of cooked meat, rather than exercising a subtle background effect.

The South African beef carcass classification system (Government Gazette No. 5092, 1993) incorporates two variables, namely age by dentition (indicating tenderness) and carcass fat cover (indicating fatness and lean yield). Age by dentition was the variable incorporated in this study, as it was deemed essential to elucidate how the tenderness of different cuts varies with age, and how the tenderness of one cut relates to that of others within the South African context. Fifteen wholesale beef cuts (Meat Science Section, 1981) are traditionally identified by the industry as representative of the portioned carcass. These cuts may be divided into two categories: those traditionally associated with a dry heat cooking method, and those traditionally associated with a moist heat cooking method.

The main objective of the study was to determine the effect of age on the tenderness-related quality characteristics of seven and eight primal cuts of beef cooked according to a dry and moist heat method respectively, from beef animals of three different age groups. The data was statistically analysed with carcass fat content as a covariant to adjust for initial differences in carcass fat content as carcass fatness influences tenderness (Dolezal *et al.*, 1982).

Since the beef carcass classification system in South Africa is a dynamic system and changes according to consumer demand, it could be useful to develop statistical models that adapt to changes in age groupings. Therefore a second objective was identified namely the prediction of the tenderness characteristics of various age groups. Determining the most reliable cut in order to predict the tenderness of the carcass was investigated as the third objective.

MATERIALS AND METHODS

Source of materials

The beef carcasses (*n* = 102) used in this study had a mass range of 190 kg to 240 kg. No specific breed was chosen. Only steers and heifers were included in the study due to the small proportion of bull carcasses currently available on the market in South Africa. The three age groups were the 0 (no permanent incisors) or A-age group, the 2 (permanent incisors) or B-age group, and the 8 tooth or C-age group. Carcasses representing the full spectrum of fat classes available in the South African market within each age group were selected. Please refer to Table 4.1 for a schematic diagram of the research design.

The carcasses were obtained on the commercial market (at the largest abattoir in the country) and had been selected by qualified classifiers. The carcasses were electrically stimulated (500 V) within 10 minutes of stunning, dressed, halved, chilled overnight at between 0°C and 5°C and were labelled and transported to the ARC-ANPI in a refrigerated truck.

TABLE 4.1
Experimental Design for Determination of Tenderness and Collagen Characteristics of Beef Carcasses

Carcasses	**Age group**			**Total number of carcasses**
	A	**B**	**C**	
All right sides: Physical composition and Chemical analysis	35	34	33	102
Left sides: Tenderness determinations Collagen determinations	21 14	20 14	20 13	61 41

Sample preparation

Each of the 102 right sides of beef was subdivided into 15 wholesale cuts (Figure 4.1) to determine its physical composition and for chemical analysis. This involved subdivision of the cuts into subcutaneous fat, meat and bone. The subcutaneous fat plus meat were cubed, thoroughly mixed and then minced first through a 5 mm and then through a 2 mm mesh plate. A representative sample of 300 g of the subcutaneous fat plus meat tissue obtained from each cut was analysed to determine the percentages of total moisture (oven-dry method), fat (Soxhlet extraction with diethyl ether for 16 hours), nitrogen (Kjeldahl-method using a Büchi 430 block digester and a Büchi 322 distilatlion unit) (N *x* 6,25 = protein) and ash (by ignition at 800°C). Moisture and fat content of samples were determined in triplicate and protein content was determined in duplicate. If the sum of the proximate values did not meet 100±1,5% samples were reanalysed. These determinations were performed according to AOAC methods (1995). The chemical analysis results were combined with the subcutaneous fat and meat (muscle and inter- and intramuscular fat) content results obtained from the physical dissections for the calculation of muscle and total fat content of each specific cut, and expressed as a percentage of carcass mass (Carroll & Conniffe, 1967).

Forty-one of the left beef sides were used for total collagen content and solubility determinations. The sides were separated into 15 wholesale cuts (at 10°C), vacuum-packaged and aged at 4°C for 10 days post-slaughter. The cuts were then deboned if applicable and analysed as indicated: chuck (hump and thick elastin sinew removed), PP, neck (visible fat removed), thin flank (visible fat removed), and shins (thick collagen sinew and visible fat removed). The epimysium was removed from the following muscles: LTP, LL, LTW, GM, SM, ST, PM, TBCL, GB and VL. Whole cuts or muscles were homogenised, vacuum-packaged and stored at -40°C until analysed for collagen content and solubility.

Sixty-one left sides were used for sensory analysis and shear force measurements. They were portioned into 15 wholesale cuts with the rump and topside deboned. The cuts were then vacuum-packaged, aged at 4°C for 10 days post-slaughter and stored at -40°C prior to sensory analysis and shear force resistance measurements. The cuts were defrosted at 6°C - 8°C for periods varying between 24 and 36 hours (depending on size) until the internal temperature reached 2°C - 5°C (American Meat Science Association (AMSA), 1978).

16 = Silverside (*M. semitendinosus* (ST))
15 = Hind shin (*M. flexor digitorum medialis* (FDM))
14 = Topside (*M. semimembranosus* (SM))
13 = Silverside (*M. gluteobiceps* (GB))
12 = Thick flank (*M. vastus lateralis* (VL))
11 = Fillet (*M. psoas major* (PM))
10 = Rump (*M. gluteus medius* (GM))
9 = Thin flank (*M. obliques abdominus externus* (OAE))
8 = Loin (*M. longissimus lumborum* (LL))
7 = Wing rib (*M. longissimus thoracis* (LTW))
6 = Prime rib (*M. longissimus thoracis* (LTP))
5 = Brisket (*M. pectoralis profundus* (PP))
4 = Chuck (*M. serratus ventralis* (SV))
3 = Shoulder (*M. triceps brachii caput longum* (TBCL))
2 = Fore shin (*M. extensor carpi radialis* (ECR))
1 = Neck (*M. biventer cervicis* (BC))

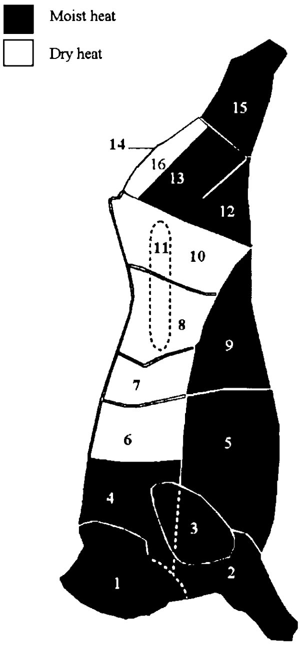

Fig 4.1: Wholesale cut from the carcass

The largest muscle in each cut was selected for evaluation of tenderness. During the various pilot studies, it became clear that the internal temperature of certain muscles, e.g. *M. semimembranosus,* was considerably different to that of the rest of the topside cut due to its anatomical position. It was therefore decided to measure the internal temperature only of the muscle to be evaluated. A J-type thermocouple placed in the geometric centre of each muscle to be evaluated, linked to a centrally controlled computer system, was used to record internal temperature. A hand-model Kane-Mane probe equipped with a T-type thermocouple was used to check the final temperature (70°C) of the cut prior to removal from the oven.

Cooking methods

Dry heat cooking methods

The following cuts (*muscles*) were used: Prime rib - 8th to 10th rib (*M. longissimus thoracis* (LTP)); Loin (*M. longissimus lumborum* (LL)); Wing rib - 11th to 13th rib (*M. longissimus thoracis* (LTW)); Rump (*M. gluteus medius* (GM)); Topside (*M. semimembranosus* (SM)); Silverside (*M. semitendinosus* (ST)) and Fillet (*M. psoas* *major* (PM)) (Weniger *et al.*, 1963). All these cuts, excluding the loin, were cooked in primal form. The cuts were roasted whole at 160°C, on a rack in an open oven pan, until the muscle to be evaluated reached an internal temperature of 70°C. The loin cuts were portioned into 25 mm thickness beefsteaks (AMSA, 1978), vacuum-packaged and stored at -40°C. The defrosted steaks were cooked according to an oven-broiling method where the meat is cooked by direct radiant heat (> 200°C) to an internal temperature of 70°C.

Moist heat cooking methods

The following cuts (*muscles*) were used: Silverside (*M. gluteobiceps* (GB)); Thick flank (*M. vastus lateralis* (VL)); Chuck (*M. serratus ventralis* (SV)); Brisket (*M. pectoralis profundus* (PP)); Neck (*M. biventer cervicis* (BC)); Shoulder (*M. triceps brachii caput longum* (TBCL)); Thin flank (*M. obliquus abdominis externus* (OAE)) and Fore as well as Hind Shins (*M. extensor carpi radialis* (ECR)) and *M. flexor digitorum medialis* (FDM)) (Nomina-Anatomica Veterinaria, 1983).

The silverside, thick flank, chuck, shoulder and neck were cooked in primal form. The brisket and thin flank cuts were formed into meat rolls and covered with mesh before ageing. Before cooking commenced, the frozen fore and hind-shins were portioned into cuts of 5 cm thickness. All the cuts were broiled at 160°C, on a rack in a covered stainless steel casserole dish, until the muscle to be evaluated reached an internal temperature of 70°C. Distilled water (100 ml) at room temperature was added to each dish before cooking commenced.

All the cuts (dry and moist) were held for a standing period of 10 minutes at room temperature following cooking. Thereafter all the different muscles were dissected and halved for sensory analysis and shear force measurements respectively. Half of the muscle designated for sensory analysis was cut up immediately after cooking. Ten cubed samples were taken from the middle of each muscle and immediately individually wrapped in foil marked with random three digit codes. These samples were then served at an internal temperature of 60°C within 30 minutes from the time the whole cut was removed from the oven. A 100 g sample of the cooked muscle was analysed to determine the percentages of total moisture, fat, nitrogen (N *x* 6,25 = protein) and ash according to AOAC methods (1995).

In order to compare age effects, the sensory panel was presented with samples of the identical muscle from the three age groups with comparable fatness levels. Samples were tasted at each of the 20 sessions during seven consecutive working days, with the order of the age groups randomised for each session. Cooking, sensory analysis and shear force resistance measurements were then performed on the following cut without any particular order of cooking for the various cuts (3 samples *x* 20 sessions *x* 15 cuts = 900 samples tasted).

Data recorded

Descriptive tenderness attributes

A ten-member, trained, descriptive sensory panel was used to evaluate the tenderness attributes of each cut. Panellists were selected and trained in accordance with the AMSA Guidelines for Cooking and Sensory Evaluation of Meat (AMSA, 1978) and the procedures of Cross *et al.* (1978). Panellists, seated in individual booths in a temperature-controlled room, received a set of three samples, wrapped and marked with randomly selected three digit codes. The colour of the samples was masked by the use of red light. Distilled water at room temperature was used to cleanse the palate between samples. Samples (1 cm ^{3}) taken from the middle of each muscle were evaluated for tenderness and residue (connective tissue amount) on an 8-point scale ("one" denoting the least favourable condition and an "eight" the most favourable).

Tenderness determination

The shear force samples were wrapped in aluminium foil and stored at 6°C - 8°C for 24 hours. They were then removed from the refrigerator and allowed to stand for up to four hours to reach room temperature (centrally controlled at 22°C) before samples were cored. The exception was the prime rib (LTP) cut which was allowed, on an experimental basis, to stand at room temperature on the same day of cooking until it reached room temperature, before samples were cored. Crouse and Koohmaraie (1990) found that neither time of storage nor storage temperature appreciably affected shear-force values or variation of shear-force within treatments. The taste panel found the LTP of the A- and B-age groups significantly ($p \leq 0,05$) more tender than from the C-age group. However, this method was not repeated with the other muscles because no significant differences were found in the shear-force measurements for the LTP.

Cylindrical cores were cut from all the muscles (using a standard 25 mm diameter bore) at room temperature, except for the LL and PP (where a 13 mm bore was used) and the OAE (for which a cherry-pitter with a 12,7 mm diameter attachment was used). These exceptions were due to the shape and size of these muscles. Due to insufficient sample material no shear force analyses were performed on the BC. Tenderness was measured as the maximum force (Newtons) required to shear a cylindrical core of cooked muscle perpendicular to the grain, at a crosshead speed of 400 mm per second. The shear force measurements were generated with a Warner Bratzler shear attachment, fitted to an Instron Universal Testing Machine Model 1140 (Instron Food Testing Instrument, 1974). Increasing values indicated greater shear forces and, therefore, tougher meat.

Collagen content and solubility

The total collagen content of each of the respective muscles/cuts was determined according to the method of Weber (1973) and hydroxyproline according to Bergman and Loxley (1963). Total collagen content was calculated as the ratio of hydroxyproline nitrogen relative to the total nitrogen content, expressed as a numeric value multiplied by 1 000 (Boccard *et al.*, 1979). Collagen solubility was determined according to a combination of the methods of Hill (1966) and Bergman and Loxley (1963), being expressed as the hydroxyproline content of the filtrate as a percentage of total hydroxyproline (filtrate plus residue).

STATISTICAL ANALYSIS

In order to establish which of the large set of correlated variates were the most important in discriminating between the age groups (A, B and C) and/or the 15 cuts, canonical variate analysis (CVA) (GENSTAT 5, 1996), also known as linear discriminant analysis, was used. Multivariate techniques, such as principal component analysis (PCA) are used to reduce a large set of variates into a smaller set, which explains most of the variation in the entire data set. PCA (GENSTAT 5, 1996) was performed on all the different variates for each of the 15 cuts, but will not be presented due to limited space (n = 5 tenderness parameters x 15 cuts = 75 plots). Through the PCA it was identified that fatness of the carcass was one of the most important gradients or factors identified in this multivariate data space (data matrix) and for that reason was used as covariant in the ANOVA-analyses. PCA is suitable when one is interested in the groupings of individuals, and as definite groupings were observed in this data set, CVA was applied. The variability in this large number of variates was firstly reduced to a smaller set of variates, which accounted for most of the variability. If there was a strong grouping or trend in the data set, usually only a few of the important variates which influence the new variate, called canonical variates (CV), were obtained. A plot of the mean scores of each group is obtained. This plot is a visual and easily understandable graphical representation of the similarity or groupings of the original age and/or cut groups. Furthermore, by correlating the scores with the original variates, the most important variates discriminating between the new groups were identified (Digby & Kempthorne, 1987). In this study the variates were the tenderness characteristics that were measured in each cut. The logarithms of the variates were used to stabilise variances.

As only the directions of the main variability in the data matrix are given attention in these analyses, the more subtle sources of variation were investigated by ANOVA-analyses (SAS, 1996) as proposed by Næs *et al.* (1996). A correlation matrix was constructed to test for correlation between the different variables. To ensure that the effect of animal age was determined and not the effect of fatness of the carcass, the percentage chemical fat of the carcass (as determined by proximate analyses for the 15 wholesale cuts and calculated for the carcass according to the relative mass of each cut) was used as covariant (X), both as natural X and X^2 in a PROC GLM (SAS, 1996) procedure. In searching for the simplest model the covariant was removed from the model if not significant (very generously at $p \geq 0{,}15$), starting with X^2 and continuing with X. Separation of the mean scores for interaction of the different variables for the various cuts for the three age groups was achieved by the application of Tukey's method (SAS, 1996).

In order to achieve the second objective, namely the prediction of the tenderness characteristics for the various age groups, regression equations ($Y = A + BX$) were used as the main model. In the regression equation age of the animal (X) was tested against the various tenderness characteristics (Y) of each cut and the entire carcass. Due to the fact that most of the data were not normally distributed the dependent variates in the equation (Y) were transformed to Y^2, Y^3, $\sqrt{Y}$ and $ln\ Y$'s (natural logs). These four transformations, together with the natural Y, were combined in forward stepwise regression analysis and tested against tenderness as analysed by the taste panel.

The above-mentioned formulae should be of a specific accuracy to obtain repeatable and reliable predictions of mean carcass and individual cut tenderness. The accuracy of these formulae is determined by the R^2 (percentage variation) and the residual standard deviation or RSD (error variance around the regression line). As very few of the $R^2 \geq 50\%$ this was not considered a reliable method of predicting the tenderness characteristics in animals. Therefore, the data were submitted to an analysis of variance for the three age groups as described above in which the R^2 and p-value of the model were also presented. During this study it became evident that this is also not a reliable method for predicting tenderness in animals. Therefore, no satisfactory statistical model was identified within the scope of this study to predict tenderness parameters of animals of different age groups accurately.

The forward stepwise regression analysis showed that tenderness can be predicted by residue at least 96% in all the cuts and a simple linear regression equation ($Y = A + BX$) would therefore be sufficient. This is in accordance with the results of Cross *et al.* (1973) who described sensory panel ratings as closely interrelated and probably mutually dependent. Therefore all the sensory panel ratings for residue were excluded from the model and the data were again submitted to forward stepwise regression analysis.

In order to determine the most reliable cut to predict tenderness of the carcass (third objective), correlation coefficients and R^2-values were determined between the tenderness characteristic obtained for a specific muscle with the mean of the same measurement of all the individual muscles combined.

RESULTS AND DISCUSSION

Effect of age on tenderness characteristics

According to the canonical variate analyses results, the first canonical variate (CV1) alone accounted for 99,8 % of the total variation in the data but the latent root was 0,8038 (should be >1). The canonical variate means for tenderness, residue and collagen solubility were positive and for shear force resistance and collagen content negative, thus CV1 clearly contrasts between these variables. The parameter discriminating between the tenderness parameters is collagen solubility (r = 0,807) as this correlated the strongest with the CV scores (horisontal). The CV mean scores are presented in Figure 4.2. Collagen solubility is therefore the largest discriminant between the three age groups and it declines with age. This result is due to the proportion of heat stable cross-links in collagen that increases with increasing animal age and is in accordance with results of many researchers such as Young and Braggins (1993), Shay and Egan (1992) and Cross *et al.* (1973). The hypothesis is therefore validated that collagen is a major determinant of the texture of cooked meat as proposed by Bailey (1989), and that it is the quality as well as the quantity that accounts for the variability.

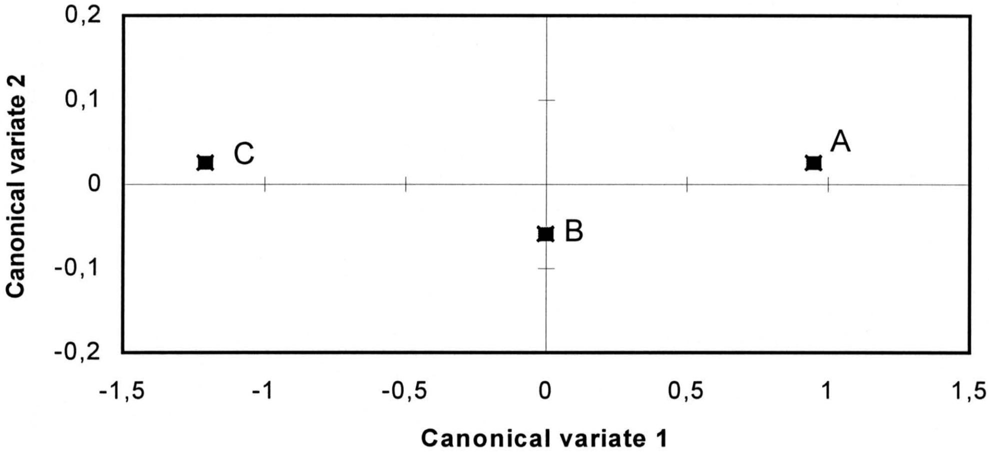

Fig. 4.2: Plot of CV mean scores of three age groups[1]

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[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

For the analyses of variance (ANOVA), the chemical analysis data were combined with the subcutaneous fat, meat (muscle and intermuscular fat) and bone content results obtained from the physical dissections for the calculation of percentages meat, total fat and bone content of each specific cut (Carroll & Conniffe, 1967). These values were summed to obtain the chemical (fat, protein and moisture) and physical composition (meat, total fat and bone) of the carcass. This percentage total fat content of the carcass was used as covariant in the PROC GLM procedure to adjust for differences between initial fat content and was 15,74% with a minimum of 8,03% and a maximum of 29,75%.

The other fat attributes measured for this data set were:

- Subcutaneous fat (%) of the carcass: Mean = 6,214; Minimum = 1,170; Maximum = 13,360;
- Proximate fat (%) in the carcass: Mean = 13,46; Minimum = 1,61; Maximum = 42,89;
- Proximate fat (%) in the cooked muscles: Mean = 4,93; Minimum = 0,98; Maximum = 26,61.

The age of the animal (Table 4.2, 4.3 and 4.4) had a significant effect on the tenderness, residue of the various muscles and collagen solubility of various cuts or muscles. According to the taste panel scores, all 15 muscles of the A-age group (0 tooth) were significantly ($p \leq 0,01$) more tender and contained less residue than those from the C-age group (8 tooth) (Table 4.2). The ST, SM, PM, GB, SV, PP, TBCL, ECR and FDM of the A-age group (0 tooth) were significantly ($p \leq 0,01$) more tender and contained less residue than those from the B-age group (2 tooth).

The two muscles in the silverside (ST and GB) and OAE of the A-age group showed significantly ($p \leq 0,01$) less resistance to shear than those from the B-age group which in turn showed significantly ($p \leq 0,01$) less resistance to shear than those from the C-age group (Table 4.3). The LTW, VL, SV and TBCL of A-age group (0 tooth) showed significantly ($p \leq 0,05$) less resistance to shear than those from the C-age group (8 tooth).

According to Table 4.4 collagen content of cuts/muscles did not differ significantly between the various age groups. The LTP, LL, ST, GB, VL, chuck, PP, neck, TBCL and thin flank were significantly ($p \leq 0,001$) more soluble in cuts/muscles obtained from the A-age group compared to the B-age group which, in turn, were significantly ($p \leq 0,001$) more soluble than cuts/muscles obtained from the C-age group. The collagen of all 16 cuts/muscles measured in the A-age group was significantly ($p \leq 0,05$) more soluble than those from the C-age group.

These results are in accordance with Shorthose and Harris (1990) who reported a significant decrease in tenderness with increased age (ranging from one to approximately 60 months old). All the objective measurements they used (Instron-compression, adhesion, Warner-Bratzler shear) indicated strong linear (and in some cases, curvilinear) relationships with animal age.

TABLE 4.2

Least Square Mean Values (± Standard Error of Mean) for Sensory Panel Traits for Muscles from Three Age Groups (Average Chemical Fat of the Carcass used as Covariant = 15,74 %)

Muscle[1]	Model		Co-variant[2]		Age						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
Tenderness (8=extremely Tender,1=extremely Tough): Cooked (Dry Heat)											
LTP	10	0,0001	0,3145	0,0328	0,0129	5,22^a	0,107	5,23^a	0,110	4,84^b	0,104
LL	5	0,0001	0,0001		0,0023	4,78^a	0,099	4,52^{ab}	0,104	4,29^b	0,099
LTW	15	0,0001	0,0001		0,0001	5,66^a	0,104	5,53^a	0,110	4,64^b	0,104
ST	22	0,0001	0,0001	0,0001	0,0001	5,80^a	0,085	5,35^b	0,089	4,56^c	0,084
GM	5	0,0001	0,0002		0,0002	5,53^a	0,093	5,29^{ab}	0,098	4,98^b	0,093
SM	12	0,0001	0,0932	0,0488	0,0001	5,33^a	0,078	4,78^b	0,084	4,41^c	0,080
PM	8	0,0001	0,0095	0,0060	0,0001	6,72^a	0,073	6,44^b	0,076	6,09^c	0,072
Cooked (Moist Heat)											
GB	29	0,0001			0,0001	5,56^a	0,091	4,73^b	0,098	3,51^c	0,093
VL	13	0,0001	0,0968	0,0323	0,0001	5,56^a	0,081	5,39^a	0,085	4,63^b	0,081
SV	18	0,0001	0,0026	0,0002	0,0001	5,74^a	0,091	5,44^b	0,096	4,53^c	0,091
PP	26	0,0001	0,0001		0,0001	4,76^a	0,097	4,16^b	0,102	2,94^c	0,100
BC	16	0,0001	0,0519	0,0494	0,0001	5,49^a	0,103	5,20^{ab}	0,111	4,04^b	0,103
TBCL	9	0,0001	0,0267	0,0136	0,0001	5,23^a	0,104	4,92^b	0,109	4,26^c	0,104
OAE	11	0,0001	0,0012	0,0013	0,0001	5,67^a	0,096	5,60^a	0,101	4,69^b	0,096
ECR&FDM	12	0,0001	0,2952	0,1057	0,0001	4,20^a	0,100	3,77^b	0,106	3,07^c	0,100
Residue (8=none, 1=abundant): Cooked (Dry Heat)											
LTP	9	0,0001	0,6241	0,1165	0,0464	5,13^a	0,100	5,07^a	0,102	4,80^b	0,097
LL	3	0,0006	0,0031		0,0192	4,61^a	0,094	4,45^{ab}	0,099	4,24^b	0,094
LTW	17	0,0001	0,0001		0,0001	5,54^a	0,100	5,35^a	0,106	4,56^b	0,101
ST	21	0,0001	0,0001	0,0001	0,0001	5,72^a	0,082	5,32^b	0,086	4,61^c	0,082
GM	5	0,0001	0,0005		0,0001	5,48^a	0,091	5,24^a	0,095	4,90^b	0,091
SM	1	0,0001	0,1573	0,1286	0,0001	5,19^a	0,078	4,72^b	0,084	4,33^c	0,080
PM	8	0,0001	0,0047	0,0035	0,0001	5,56^a	0,065	6,33^b	0,069	5,99^c	0,065
Cooked (Moist Heat)											
GB	28	0,0001	0,1391		0,0001	5,47^a	0,093	4,70^b	0,098	3,51^c	0,094
VL	11	0,0001	0,0012		0,0001	5,34^a	0,080	5,14^a	0,084	4,49^b	0,081
SV	19	0,0001	0,0406	0,0056	0,0001	5,62^a	0,086	5,23^b	0,090	4,39^c	0,085
PP	25	0,0001	0,0001		0,0001	4,52^a	0,091	4,06^b	0,096	2,88^c	0,093
BC	11	0,0001	0,0522	0,0411	0,0001	5,04^a	0,104	4,91^a	0,113	3,94^b	0,104
TBCL	9	0,0001	0,0632	0,0268	0,0001	4,92^a	0,096	4,62^b	0,101	3,98^c	0,096
OAE	11	0,0001	0,8448	0,0001	0,0001	5,36^a	0,096	5,22^a	0,101	4,44^b	0,096
ECR&FDM	11	0,0001	0,0003		0,0001	3,94^a	0,100	3,54^b	0,105	2,86^c	0,100

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

^{abc}Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 4.3
Least Square Mean Values (± Standard Error of Mean) for Shear Force Resistance (N/2,54cm) for Muscles Obtained from Three Age Groups (Average Chemical Fat of the Carcass Covariant = 15,74%)

Muscle [1]	Model		Co-variant[2]		Age						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
Cooked (Dry Heat)											
LTP	11	0,0777	0,0169		0,5951	127,39	7,792	117,04	8,009	118,24	7,618
LL [3]	11	0,1601	0,0693	0,0428	0,6909	56,51	2,988	58,34	3,145	60,16	2,983
LTW	23	0,0022	0,0077		0,0264	$97,84^{a}$	5,769	$96,76^{a}$	6,242	$117,62^{b}$	5,919
ST	29	0,0006	0,1003	0,0936	0,0003	$91,83^{a}$	3,538	$101,26^{b}$	3,724	$113,62^{c}$	3,532
GM	29	0,0008	0,0001	0,0001	0,0866	95,76	3,310	92,92	3,400	103,14	3,232
SM	2	0,5058			0,5058	135,06	5,437	128,32	6,011	137,82	5,703
PM	13	0,0842	0,1694	0,0810	0,6621	80,84	2,701	78,28	2,844	77,51	2,697
Cooked (Moist Heat)											
GB	50	0,0001			0,0001	$85,00^{a}$	6,248	$112,77^{b}$	6,553	$153,63^{c}$	6,553
VL	20	0,0014			0,0014	$95,99^{a}$	4,964	$104,13^{a}$	5,342	$122,74^{b}$	5,081
SV	18	0,0128	0,1141		0,0190	$58,41^{a}$	2,853	$63,07^{ab}$	3,018	$70,33^{b}$	2,937
PP [3]	47	0,0001	0,0008		0,0001	42,11	2,031	47,14	2,206	57,91	2,088
TBCL	20	0,0114	0,0302	0,0386	0,0101	$92,82^{a}$	4,272	$87,71^{a}$	4,612	$107,20^{b}$	4,484
OAE [3]	40	0,0001	0,0003		0,0002	$82,42^{a}$	5,818	$102,72^{b}$	6,146	$118,91^{c}$	5,832
ECR&FDM	24	0,0004			0,0004	52,74	3,749	62,41	4,034	75,52	3,837

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - M. flexor digitorum medialis

[2] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

[3] LL and PP cored with a 13 mm diameter bore and OAE with a 12,7 mm diameter cherry-pitter

However, when considering results from taste panel evaluations of the meat, they found that age did not have a constant effect on tenderness of the PM muscles and that the results for the other muscles all showed non-linearity ($p \leq 0,001$). Covington *et al.* (1970) did not find any significant difference in shear force measurements among *longissimus* steaks for the three maturity groups studied (12 to 18, 18 to 30 and 30 to 38 months). Davis *et al.* (1979) found that neither collagen content nor collagen solubility was significantly related to tenderness of cooked beef from carcasses of the A- (very young) or B- (young) maturity.

TABLE 4.4

Least Square Mean Values (± Standard Error of Mean) for Collagen Traits for Muscles/cuts Obtained from Three Age Groups (Average Chemical Fat of the Carcass Covariant = 15,74%)

Muscle [1]	Model		Co-variant [2]		Age						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
Collagen Content (Hypro N /Total Nx10^3): Cooked (Dry Heat)											
LTP	6	0,2769			0,2769	3,05	0,308	3,53	0,318	3,78	0,342
LL	9	0,3212	0,1048		0,8023	2,90	0,161	2,79	0,161	2,93	0,168
LTW	1	0,7700			0,7700	2,68	0,128	2,59	0,132	2,70	0,142
ST	12	0,0808			0,0808	4,31	0,272	4,58	0,281	5,23	0,302
GM	4	0,4021			0,4021	3,67	0,179	3,32	0,185	3,47	0,198
SM	0,4	0,9271			0,9271	3,00	0,086	3,03	0,089	2,98	0,095
PM	10	0,1242			0,1242	2,23	0,173	2,76	0,179	2,52	0,192
Cooked (Moist Heat)											
GB	2	0,6383			0,6383	6,26	0,344	6,09	0,355	5,78	0,382
VL	2	0,7141			0,7141	4,04	0,176	4,18	0,196	3,95	0,204
Chuck	18	0,1628	0,1478	0,0998	0,1613	8,27	0,437	8,46	0,487	9,49	0,481
PP	29	0,0051	0,0024		0,1500	6,26	0,379	7,28	0,381	7,08	0,397
Neck	2	0,7216			0,7216	10,88	0,938	11,98	0,968	11,34	1,040
TBCL	6	0,3420			0,3420	5,02	0,380	5,21	0,394	5,90	0,466
Thin flank	3	0,5805			0,5805	11,85	0,721	13,00	0,912	11,89	0,912
Fore shin	10	0,1431			0,1431	13,49	0,798	15,39	0,798	13,24	0,900
Hind shin	21	0,0366	0,0145		0,4982	18,80	0,965	20,43	1,015	19,25	1,058
Collagen Solubility (%): Cooked (Dry Heat)											
LTP	50	0,0001			0,0001	19,88^a	0,846	14,98^b	0,905	12,14^c	0,939
LL	29	0,0008			0,0008	21,54^a	1,352	17,62^b	1,396	13,23^c	1,499
LTW	24	0,0036			0,0036	18,88^a	1,314	14,70^b	1,357	11,94^b	1,457
ST	47	0,0001			0,0001	19,01^a	0,857	15,95^b	0,885	11,36^c	0,951
GM	44	0,0003	0,0456	0,0979	0,0006	20,26^a	1,340	16,80^a	1,384	11,94^b	1,413
SM	38	0,0005	0,0602		0,0011	14,98^a	0,869	12,28^b	0,873	9,87^b	0,909
PM	47	0,0001	0,0566		0,0001	16,01^a	0,725	14,64^a	0,728	10,85^b	0,759
Cooked (Moist Heat)											
GB	49	0,0001			0,0001	19,96^a	0,905	16,56^b	0,935	11,56^c	1,004
VL	48	0,0001	0,0026		0,0005	23,90^a	1,420	19,39^b	1,426	14,82^c	1,548
Chuck	50	0,0001	0,0373		0,0373	28,72^a	1,544	21,90^b	1,551	16,51^c	1,616
PP	41	0,0002	0,0830		0,0003	17,77^a	0,896	14,76^b	0,900	11,96^c	0,938
Neck	48	0,0001			0,0001	25,74^a	1,226	19,98^b	1,266	14,56^c	1,360
TBCL	48	0,0001			0,0001	27,84^a	1,187	21,73^b	1,226	17,10^c	1,317
Thin flank	59	0,0001	0,0883	0,1044	0,0001	29,72^a	1,288	22,39^b	1,331	17,02^c	1,359
Fore shin	55	0,0001	0,0338	0,0506	0,0001	35,61^a	1,753	32,68^a	1,811	20,55^b	1,849
Hind shin	37	0,0020	0,0493	0,0731	0,0015	26,50^a	1,881	23,34^a	1,943	15,93^b	1,984

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobicepss*; VL - *M. vastus lateralis*; PP - *M. pectoralis profundus*; TBCL - *M. triceps brachii caput longum*

[2] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

Results of this study are in agreement with Cross *et al.* (1973) who found that initial and fibre tenderness ratings, amount of connective tissue ratings, shear force values, percentages of fat on a moisture free basis and the amount of soluble collagen differed significantly ($p \leq 0,05$) among age groups (1 yr vs. 4 yr vs. 10 yr), with no significant difference in collagen content between the groups. Herring *et al.* (1967) also reported that collagen solubility decreased significantly with each advancing maturity group (USDA meat-grading standards) in both *longissimus dorsi* and *semimembranosus*,, and Young and Braggins (1993) who found that in both the SM and GM the collagen solubility declined with age. Collagen content remained unchanged in the SM and GM (Young & Braggins, 1993) and *longissimus dorsi* between the age groups but the *semimembranosus* in the E-age group (older) had more collagen ($p \leq 0,05$) than in the A- (very young) and B- (young) maturity groups and concentrations (Herring *et al.*, 1967). In the current study no significant difference was found in the collagen content (%) between the different age groups for any of the cuts/muscles evaluated when analysed on an equal chemical fat content. Significant differences in collagen solubility were found in 12 of the 16 cuts from carcasses of the A- (0 teeth) and B- (2 teeth) age groups.

Discrimination between cuts/muscles

According to the results of canonical variate analyses the first two canonical variates (CV1 and CV2) accounted for 95,5% of the total variation in the data, with latent roots 10,1 and 1,0 (should be >1). The canonical variate means for tenderness, residue and shear force resistance was negative and for collagen content and collagen solubility positive, thus CV1 clearly contrasts between the groups of cuts. The variate mainly discriminating between the tenderness characteristics for the different cuts is collagen content ($r = 0,986$) as this correlated the strongest with the CV1 scores. Shear force resistance ($r = -0,702$) mainly discriminated between groups in the CV2 for the different cuts. The CV mean scores are presented in Figure 4.3.

Inspection of the graphical representation of the results (points close together are similar and those far apart are dissimilar) shows that, PM, LTW, SM, LTP, GM and LL are contrasted against the ECR, FDM, OAE, SV and PP according to collagen with the former being low in collagen and the latter high on the CV1 axis (horisontal). This difference in collagen content between the various muscles is also tabulated by Seideman (1986) in descending order as ST>GB>LL>SM>PM. Light *et al.* (1985) also reported a higher total collagen content in the tougher muscles with PP higher in total collagen content than *longissimus dorsi* (in this instance represented by LL, LTP and LTW), which, in turn, contained more collagen than the PM.

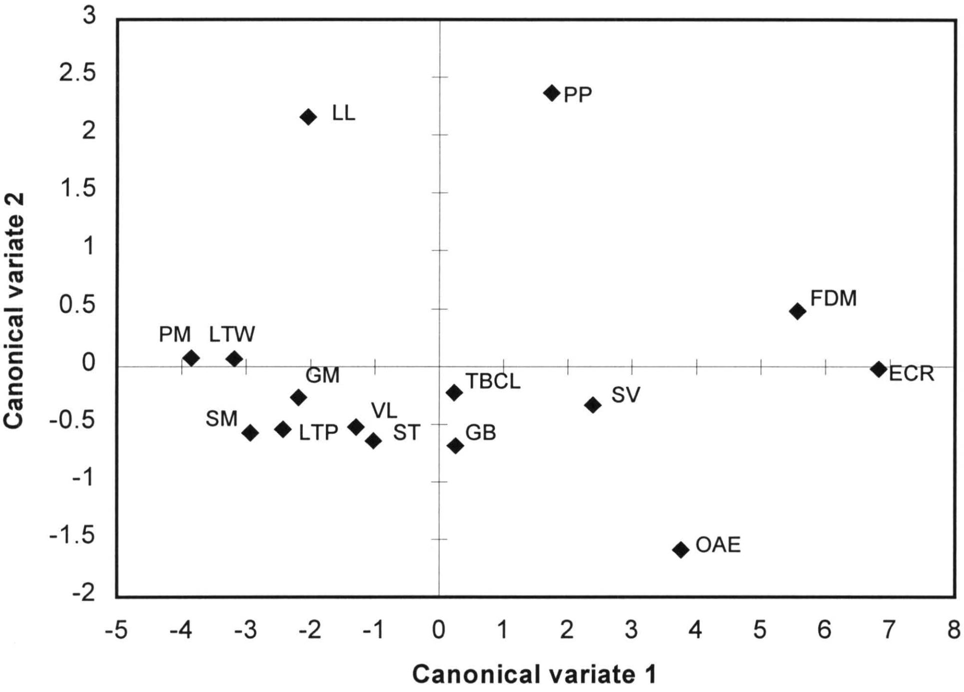

Fig. 4.3: Plot of CV mean scores of various cuts[1]

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[1] LTP – *M. longissimus thoracis*; LL – *M. longissimus lumborum*; LTW – *M. longissimus thoracis*; ST – *M. semitendinosus*; GM – *M. gluteus medius*; SM – *M. semimembranosus*; PM – *M. psoas major*; GB – *M. gluteobiceps*; VL – *M. vastus lateralis*; SV – *M. serratus ventralis*; PP – *M. pectoralis profundus*; BC – *M. biventer cervicis*; TBCL – *M. triceps brachii caput longum*; OAE – *M. obliquus abdominis externus*; ECR – *M. extensor carpi radialis* and FDM – *M. flexor digitorum medialis*

In studying CV2 (vertical axis) and taking into consideration the fact that CV2 only accounted for 8,8% of the total 95,5%, the OAE (cherry pipper attachment) showed the highest resistance to shear and the LL and PP (only two cuts analysed with a 13 mm bore) the lowest. In contrasting the muscles that were analysed with the identical 25 mm cores and cooked according to a dry heat cooking method, the PM and LTW contrasted against ST, with the former showing the least resistance to shear. With contrasting cuts cooked according to a moist heat cooking method the FDM and ECR showed the least resistance to shear and the GB the highest. This is in accordance with a study of Mc Keith *et al.* (1985) who reported the lowest scores (in ascending order) for PM, LL, GM, ST, LD-Rib (similar to LTP and LTW) and the highest (in descending order) for SM and GB. Even in raw meat PM was generally the most tender (Lepetit & Sale, 1985).

Table 4.5 gives the mean scores (CVAs) for the determination of the tenderness characteristics of the various cuts for the three age groups. An ANOVA or similar analysis that tests for differences between the means e.g. Bonferoni was not performed due to the fact that the muscles were not similarly treated. With the exception of the OAE, the sensory panel for muscle fibre tenderness and the amount of detectable connective tissue residue almost identically ranked the cuts. The PM was the most tender muscle, had the least amount of detectable connective tissue residue and the lowest collagen content of all the muscles. The ranking order of these findings are consistent with the results of Mc Keith *et al.* (1985) in which the properties of 13 major beef muscles were studied.

The tenderness values (muscle fibre tenderness, residual connective tissue and shear force resistance) found in this study for the various muscles are similar to those of Shorthose and Harris (1990) who reported tenderness in order of most to least PM>GM>SM>GB in animals aged 10 - 60 months. Seideman (1986) reported the collagen content of various muscles (14 month old steers) in more or less the same order ST>GB>LD>SM>PM and the quantity of soluble collagen GB>PM>SM. The ECR and FDM were the least tender and contained the highest amount of connective tissue (residual and as determined), despite the fact that these muscles contained the most soluble collagen and that it was cooked according to a moist heat cooking method. However, the shear force resistance results showed that ECR and FDM had the least resistance to shear with the exception of two muscles. This is in contrast to the OAE, which was high in collagen, high in soluble collagen and was evaluated by the panel as very tender. According to Young and Braggins (1993) their panel data showed that collagen concentration as opposed to solubility, was the more important determinant of eating quality, whereas shear data were more clearly related to solubility.

As expected, the cuts in which the epimysium had not been removed prior to the determination of the collagen parameters contained on average the highest amount of collagen (ECR>FDM>OAE>BC>SV>PP). The collagen solubility of these cuts formed a similar pattern with the exception of the PP of which the collagen was much less soluble. This could explain the low sensory panel scores for tenderness and residue for the PP.

TABLE 4.5
Ranking of 16 Muscles[1] According to Tenderness and Collagen Characteristics

Score	Muscle fibre tenderness [2]	Residual connective tissue [3]	Shear force resistance [4]	Collagen content[5]	Collagen solubility [6]
1	PM (6,402)	PM (6,284)	SM (133,96)	ECR$^{\text{(all)}}$[7] (19,23)	FDM$^{\text{(all)}}$ (30,19)
2	OAE$^{\text{(moist)}}$[8] (5,316)	GM (5,223)	LTP (120,43)	FDM$^{\text{(all)}}$ (13,97)	OAE$^{\text{(all)}}$ (23,82)
3	GM (5,292)	ST (5,221)	GB (116,10)	OAE$^{\text{(all)}}$ (12,12)	ECR$^{\text{(all)}}$ (23,14)
4	LTW (5,277)	LTW (5,144)	VL (107,55)	BC$^{\text{(all)}}$ (11,602)	SV$^{\text{(all)}}$ (22,98)
5	ST (5,244)	SV (5,076)	LTW (107,07)	SV$^{\text{(all)}}$ (8,859)	TBCL (22,74)
6	SV$^{\text{(moist)}}$ (5,231)	OAE (5,031)	ST (102,05)	PP$^{\text{(all)}}$ (6,829)	BC$^{\text{(all)}}$ (20,78)
7	VL$^{\text{(moist)}}$ (5,189)	LTP (5,007)	OAE (100,48)	GB (5,972)	VL (20,22)
8	LTP (5,107)	VL (4,984)	GM (97,71)	TBCL (5,425)	LL (18,06)
9	BC$^{\text{(moist)}}$ (4,900)	SM (4,777)	TBCL (95,79)	ST (4,699)	GB (16,41)
10	SM (4,867)	BC (4,613)	PM (79,10)	VL (4,063)	GM (16,29)
11	TBCL$^{\text{(moist)}}$ (4,808)	GB (4,574)	SV (67,52)	GM (3,501)	LTP (16,01)
12	GB$^{\text{(moist)}}$ (4,608)	TBCL (4,518	ECR (63,42)	LTP (3,429)	ST (15,82)
13	LL (4,542)	LL (4,444)	FDM (63,42)	SM (2,995)	LTW (15,42)
14	PP$^{\text{(moist)}}$ (3,967)	PP (3,830)	LL (58,17)	LL (2,906)	PP$^{\text{(all)}}$ (14,93)
15	ECR$^{\text{(moist)}}$ (3,663)	ECR (3,429)	PP (45,43)	LTW (2,653)	PM (13,96)
16	FDM$^{\text{(moist)}}$ (3,663)	FDM (3,429)	_	PM (2,430)	SM (12,70)

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; ST - *M. semitendinosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] 8 = Extremely tender, 1 = Extremely tough

[3] 8 = None, 1 = Abundant

[4] N/2,54 cm

[5] Hypro N/Total N x 10^3

[6] %

[7] All: With epimysium

[8] Moist heat cooking method

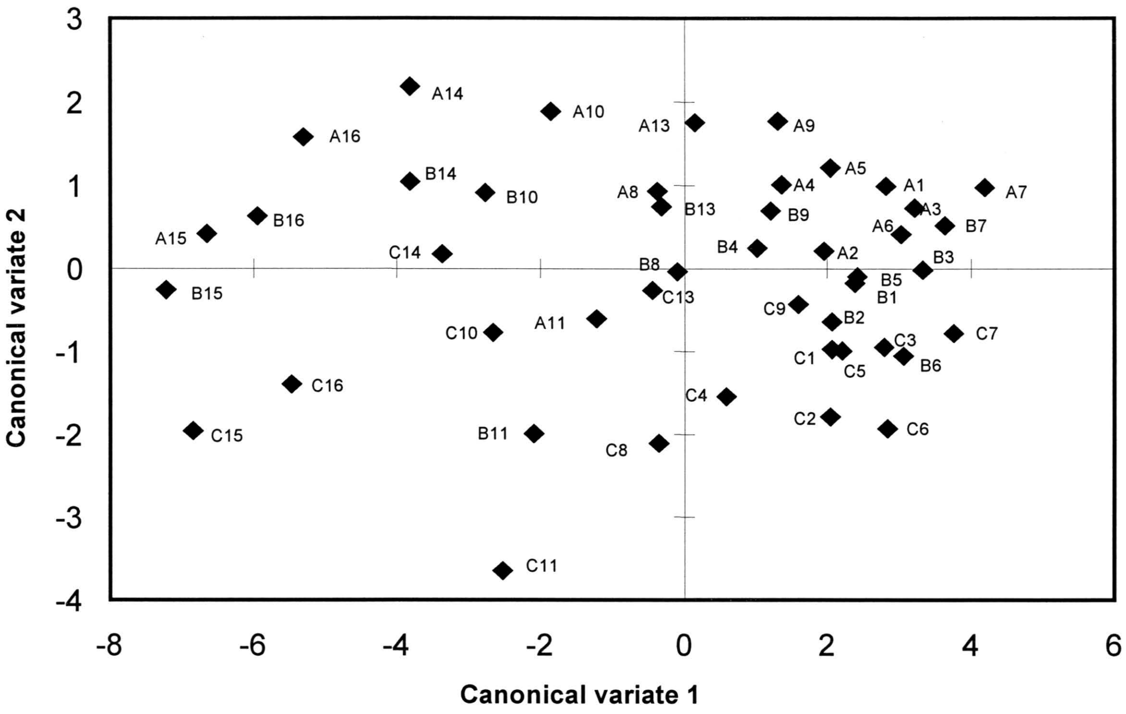

Fig. 4.4: Plot of CV Means Scores of Age groups[1] by Cuts[2]

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[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

[2] 1 – *M. longissimus thoracis (LTP)*; 2 – *M. longissimus lumborum (LL)*; 3 – *M. longissimus thoracis (LTW)*; 4 – *M. semitendinosus (ST)*; 5 – *M. gluteus medius (GM)*; 6 – *M. semimembranosus (SM)*; 7 – *M. psoas major (PM)*; 8 – *M. gluteobiceps (GB)*; 9 – *M. vastus lateralis (VL)*; 10 – *M. serratus ventralis (SV)*; 11 – *M. pectoralis profundus (PP)*; 12 – *M. biventer cervicis (BC)*; 13 – *M. triceps brachii caput longum (TBCL)*; 14 – *M. obliquus abdominis externus (OAE)*; 15 – *M. extensor carpi radialis (ECR)* and 16 – *M. flexor digitorumi medialis (FDM)*

Effect of age by cut

According to the canonical variate analyses, the first two canonical variates (CV1 and CV2) accounted for 89,2% of the total variation in the data, with latent roots 10,9 and 1,7. The canonical variate means for tenderness, residue and shear force resistance were positive and for collagen content and collagen solubility negative, thus CV1 clearly contrasts between these variables. The parameter discriminating between the tenderness parameters for the different cuts is collagen content (r = -0,985) as this correlated the strongest with the CV1 scores. Collagen solubility (r = 0,769) and tenderness (r = 0,615) is contrasted by CV2 for the different cuts. The CV mean scores are presented in Figure 4.4. Due to the fact that all three age groups are neatly grouped together for each cut, it indicates that the differences between cuts are much more discriminating than for age, also indicated by the latent root < 1.

The correlation of age with tenderness

In the previous section it was shown that the overall tenderness, residue and collagen solubility of beef carcass cuts were closely and significantly ($p \leq 0,05$) related to animal age. To determine whether these relationships were linear, a correlation matrix was constructed and it is summarised in Tables 4.6 and 4.7. Tenderness and residue, as evaluated by the sensory panel for the various muscles had significant correlation of between r = -0,312 in the GM and r = -0,348 ($p \leq 0,05$) in the VL respectively, and r = -0,708 and r = -0,675 ($p \leq 0,001$) respectively in the FDM, with age of the animal.

Shear force resistance of the various muscles studied had a lower order of significant correlation (between r = 0,410 with $p \leq 0,05$ for the VL and r = 0,436 with $p \leq 0,01$ for the ST) with age, with the exception of the GB (r = 0,750 with $p \leq 0,001$) and the ECR (r = 0,566 with $p \leq 0,01$), than those generally found for tenderness and residue (Table 4.6). This can probably be explained by the fact that shear-force measures myofibrillar toughness and in this study myofibrillar toughness has been reduced to a low level by electrical stimulation and ageing (Bouton *et al.*, 1975). Shorthose and Harris (1990) also found that initial yield values, which are associated with myofibrillar toughness, had a variable and low dependence on animal age.

TABLE 4.6
Correlation Coefficient (r) of Tenderness Related Characteristics of Muscles with Age as Independent Variable

Muscle [1]	Dependent Variables				
	Tenderness [2]	Residue [3]	Shear Force Resistance [3]	Collagen Content [5]	Collagen Solubility [6]
LTP	-0,186	-0,192	-0,108	0,239	-0,638***
LL	-0,247	-0,231	0,167	0,048	-0,590***
LTW	-0,077	-0,092	0,024	-0,064	-0,412*
ST	-0,547***	-0,517***	0,436**	0,308	-0,678***
GM	-0,312*	-0,374*	0,065	-0,095	-0,553***
SM	-0,473**	-0,445**	-0,030	-0,001	-0,566***
PM	-0,403**	-0,393**	-0,035	0,164	-0,653***
GB	-0,674***	-0,673***	0,750***	-0,154	-0,698***
VL	-0,396*	-0,348*	0,410*	-0,065	-0,574***
SV	-0,418*	-0,437*	0,086	0,211	-0,690***
PP	-0,666***	-0,691***	0,215	0,175	-0,513**
BC	-0,583**	-0,530	-	0,010	-0,669***
TBCL	-0,539**	-0,526**	0,424*	0,289	-0,658***
OAE	-0,455*	-0,419*	0,440*	0,025	-0,735***
ECR	-0,694***	-0,663***	0,566**	-0,044	-0,696***
FDM	-0,708***	-0,675***	0,437*	-0,198	-0,727***

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] 8 = Extremely tender, 1 = Extremely tough

[3] 8 = None, 1 = Abundant

[4] N/2,54 cm

[5] Hypro N/Total N X 10^3

[6] %

* p ≤ 0,05
** p ≤ 0,01
*** p ≤ 0,001

The age of the animal was not significantly correlated with collagen content (between r = 0,001 with p > 0,05 in the SM and r = 0,308 with p > 0,05 in the ST). However, for all 16 muscles age negatively correlated with collagen solubility (between r = -0,412 with p ≤ 0,01 in the LTW and r = -0,735 with p ≤ 0,001 in the OAE). Many studies concerning the relationship of the total amount of collagen to meat tenderness have shown that as tenderness decreases due to increased animal age there is essentially no change in the total amount of collagen present in the muscle (Dutson, 1974; Prost *et al.*, 1975). Boccard *et al.* (1979) showed that in cattle from 16 months onwards a constant level of collagen content was reached and maintained. Shimokomaki *et al.* (1972)

reported that as the proportion of stable cross links increases with age, the heat denatured collagen fibres in the cooked meat become stronger, thus making the collagen less soluble and the meat less tenderness.

The correlation between the tenderness characteristics

The correlation coefficient between tenderness and residue was highly significant ($p \leq 0,001$) for all the muscles studied (Table 4.7). With the exception of ratings for connective tissue, Cross *et al.* (1973) found that sensory panel ratings were closely interrelated and probably mutually dependant. Brady and Hunecke (1985) also found very strong correlation's between the sensory characteristics of chewiness, hardness and tenderness and speculated that this would indicate that these parameters were measuring either the same element of tenderness or ones that were strongly related.

Tenderness and shear force resistance measurements showed a high correlation of between $r = -0,850$ with $p \leq 0,001$ for the ST and $r = -0,463$ with $p \leq 0,01$ for the SM in this study, even though different core diameters were used for the LL ($r = -0,653$ with $p \leq 0,001$) and PP ($r = -0,554$ with $p \leq 0,01$) and that a cherry pitter attachment was used for the OAE ($r = -0,471$ with $p \leq 0,05$). These results are in accordance to those of Crouse and Smith (1978) reported a significant ($p \leq 0,001$) correlation of $r = -0,62$ between tenderness and shear force values. However, Harris (1976) cautions against putting too much emphasis on the results of only one type of mechanical device of tenderness, as a single objective device is not sensitive to the same structural components that influence the taste panel assessment. Several criteria should rather be used to express the complex perception of tenderness in meat, because the relationship between mechanical measurements of tenderness and panel assessments has not been definitely established. Mechanical devices also differ in sensitivity and reproducibility (Sharrah *et al.*, 1965). The expansion of instrumental-sensory texture approaches that yield similar results is certainly an important area for further research (Berry, 1983).

In the present study the correlation between tenderness and collagen content was not significant. The correlation between tenderness and collagen solubility were low even if significant (between $r = -0,337$ in the VL with $p \leq 0,05$ and $r = 0,452$ with $p \leq 0,01$ in the SV for collagen solubility, with the exceptions of ECR ($r = 0,597$ and $p \leq 0,01$) and the FDM ($r = 0,668$ and $p \leq 0,001$). This is similar to the findings of Mc Keith *et* *al.* (1985) that total collagen content was not a good predictor of overall tenderness for thirteen muscles ($r = -0{,}10$; $p > 0{,}05$). Herring *et al.* (1967) previously also found that collagen content was not related ($p > 0{,}05$) to sensory tenderness in either the *longissimus dorsi* ($r = -0{,}42$) or *semimembranosus* ($r = -0{,}48$), but found that collagen solubility was related to tenderness in both muscles ($r = 0{,}77$ and $0{,}81$ with $p \leq 0{,}01$ respectively). Young and Braggins (1993) also reported a low correlation between collagen solubility and tenderness ($r = 0{,}38$; $p > 0{,}05$).

TABLE 4.7
Correlation Coefficient (r) of Residue and Shear Force Resistance of Muscles with Tenderness as Independent Variable

Muscle [1]	**Dependent Variables**			
	Residue [2]	**Shear Force** [3]	**Collagen Content** [4]	**Collagen Solubility** [5]
LTP	0,977***	-0,785***	0,120	0,042
LL	0,976***	-0,653***	0,303	-0,007
LTW	0,982***	-0,848***	0,028	-0,018
ST	0,989***	-0,850***	-0,244	0,361*
GM	0,974***	-0,547***	0,127	0,222
SM	0,985***	-0,463**	0,058	0,359*
PM	0,970***	-0,532***	-0,138	0,112
GB	0,990***	-0,797***	0,140	0,387**
VL	0,971***	-0,803***	-0,021	0,337*
SV	0,983***	-0,766***	0,008	0,452**
PP	0,973***	-0,554**	-0,256	0,323
BC	0,972***	-	0,039	0,359
TBCL	0,940***	-0,604**	-0,219	0,437*
OAE	0,981***	-0,471*	0,254	0,280
ECR	0,968***	-0,676***	-0,100	0,597**
FDM	0,971***	-0,557**	0,217	0,668***

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] 8 = None, 1 = Abundant

[3] N/2,54 cm

[4] Hypro N/Total N x 10^3

[5] %

* $p \leq 0{,}05$
** $p \leq 0{,}01$
*** $p \leq 0{,}001$

The relationship between collagen solubility and age is very strong but not linear, based on the results from:

- The canonical variate analysis: collagen solubility is the main discriminate between the three age groups and that it declines with age.
- ANOVA-analysis: showed that collagen content of the same muscle did not differ significantly between the ages, but that all 16 cuts of the A-age group were significantly more soluble than those of the C-age group.

This is in accordance to Tornberg (1996) who described the relationship between mechanical and sensory data- as non-linear (S-shaped as reported by Harris and Shorthose, 1988), due to non-linearity in the sensory evaluation and the fact that muscle fibre orientation is easier to control in instrumental than in sensory evaluation.

Prediction of tenderness

Stepwise regression analysis was used to show the significant factors affecting tenderness. The R^2 values in Table 4.8 accounted for between 73,0% and 20,6% of the variation in taste panel scores for tenderness, e.g., in the most simplistic equation of $Y = A + BX$, depending on the muscle and age group. For instance the tenderness (Y) of the LTP for all three the age groups can be predicted with 72,4% accuracy, viz.

$$Y = -0{,}58 - 0{,}02\, Instron - 0{,}065\, Age + 0{,}0076\, KWTsubf + 0{,}107\, Cmuscle.$$

However, only the attributes, R^2 values and p-values are listed in Table 4.8 and not the full equations due to limited space[1]. Shorthose and Harris (1990) reported in a similar forward stepwise regression analysis that tenderness (T) can be expressed as an equation with a Warner Bratzler shear measurement of peak force (PF) and Instron compression measurements (IC) values which accounted for 70,2% of the variation in taste panel tenderness scored, viz. $T = -1{,}04 + 1{,}157\, PF - 3{,}24\, IC$ (both expressed in terms of kg).

Determine the most reliable cut to predict tenderness

Bouton *et al.* (1978) reported that muscles selected for testing meat quality are often picked for reasons of convenience, rather than how their properties reflect the properties of other muscles in the carcass.

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[1] Annexure C

TABLE 4.8

Forward Stepwise Regression Analysis[1] for the Prediction of Tenderness without Sensory Evaluation Scores

Muscle[2]	All Ages			A-Age			B-Age			C-Age		
	Attribute	R^2	p-Value	Attribute	R^2	p-Value	Attribute	R^2	p-Value	Attribute	R^2	p-Value
LTP	Instron Age KWTsubf Cmusl	62,4 68,1 71,0 72,4	0,001 0,001 0,001 0,001	Instron	75,7	0,001	Instron KWTsubf Csubf	55,1 65,3 71,3	0,001 0,001 0,001	Instron Tbone	65,3 71,9	0,001 0,001
LL	Instron Cbone	39,0 42,9	0,001 0,001	Instron	18,1	0,031	Instron	43,5	0,001	Instron Cbone	39,0 52,5	0,001
LTW	Instron	73,0	0,001	Instron Rprot	66,8 76,4	0,001 0,001	Instron	65,7	0,001	Instron	75,1	0,001
ST	Instron Age	72,6 73,8	0,001 0,001	Instron	60,2	0,001	Instron	58,2	0,001	Instron	68,4	0,001
GM	Cbone Instron Rprot	26,0 48,3 50,6	0,001 0,001 0,001	Tbone	18,9	0,032	Cbone Instron	20,6 69,9	0,029 0,001	Cbone Instron	33,9 50,2	0,003 0,001
SM	Age Instron	20,6 38,2	0,001 0,001	Tmeat	30,9	0,005	Instron Tbone Rfat	42,3 52,6 74,6	0,002 0,001 0,001	Instron	35,9	0,003
PM	Instron Age LNCsubf	20,8 36,6 42,9	0,001 0,001 0,001	Instron LNCfatcr Rmoist TRRfat	42,5 62,7 78,7 82,0	0,001 0,001 0,001 0,001	Instron	17,6	0,042	Instron	35,6	0,001
GB	Instron Age LNTsubf SQCfatcr Csubf Tmeat	57,8 62,2 66,0 68,2 70,6 72,5	0,001 0,001 0,001 0,001 0,001 0,001	Cmeat	40,5	0,001	Instron	45,0	0,001	Instron LNTsubf SQCfatcr	32,7 42,3 52,4	0,004 0,003 0,001
VL	Instron Age	63,5 67,0	0,001 0,001	Instron LNRFat	31,3 44,8	0,005 0,005	Instron	46,8	0,001	Instron	66,3	0,001
SV	Instron Age Tbone	60,0 73,0 75,5	0,001 0,001 0,001	Instron SQSEfat Rprot	60,6 70,8 77,5	0,001 0,001 0,001	Instron	72,6	0,001	Instron Tmusl	53,6 65,5	0,001 0,001
PP	Age Instron	40,0 55,4	0,001 0,001				Instron	43,3	0,016	Instron	23,5	0,039
BC	Age Rprot	28,9 44,8	0,001 0,001	Rprot LNCsubf	41,6 54,3	0,004 0,001	TRRfat	47,1	0,012	Rprot	20,9	0,057
TBCL	Age Tbone LNSEfat Cmusl	30,4 38,9 44,5 49,7	0,001 0,001 0,001 0,001	Instron Tmeat	27,4 63,9	0,026 0,001	Rprot	34,8	0,020	Instron	18,3	0,055
OAE	Instron Age	25,4 30,6	0,001 0,001	Tmeat TRCFatcr	42,1 57,2	0,018 0,014	Instron	40,4	0,021	Instron	25,8	0,031
ECR& FDM	Age Cbone Instron	39,5 47,8 50,5	0,001 0,001 0,001				Instron	57,7	0,001	Instron	41,0	0,006

[1] *Carcass parameters (%):* Cfatcr - Proximate fat content of carcass; Csubf - Subcutaneous fat of carcass; Cmusl - Muscle content of carcass; Cbone - Bone content of carcass; Cmeat - Meat contant (Csubf and Cmusl) of carcass;
Cut parameters (%): Rfat - Proximate fat content of cut; Rprot - Protein content of cut; Rmoist - Moisture content of cut; Tsubf - Subcutaneous fat of cut; Tmusl - Muscle content of cut; Tbone - Bone content of cut; Tmeat - Meat content (Tsubf and Tmusl) of cut; SEfat - Proximate fat in cooked muscle; *Transformations:* LN - Log X; SQ -$\sqrt{x}$; KW – X^2; TR – X^3

[2] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

TABLE 4.9
Correlation of Sensory Tenderness of Muscles with the Carcass Sensory Tenderness Value

Muscle [1]	Correlation coefficient	R-Squared model	p-Value	Std.Err.Est. model	Slope p-value	Intercept p-value
VL	0,81	66,00	0,001	0,45	0,001	0,07
SM	0,80	63,77	0,001	0,48	0,001	0,44
TBCL	0,78	61,03	0,001	0,58	0,001	0,58
GB	0,76	57,17	0,001	0,80	0,001	0,01
ST	0,75	55,57	0,001	0,70	0,001	0,75
SV	0,74	55,23	0,001	0,69	0,001	0,81
OAE	0,73	52,93	0,001	0,70	0,001	0,85
LTW	0,73	52,70	0,001	0,79	0,001	0,45
BC	0,72	51,93	0,001	0,78	0,001	0,30
PP	0,70	48,99	0,001	0,86	0,001	0,01
FDM	0,69	47,19	0,001	0,58	0,001	0,79
ECR	0,69	47,19	0,001	0,58	0,001	0,79
LTP	0,68	46,81	0,001	0,79	0,001	0,98
GM	0,64	40,73	0,001	0,58	0,001	0,00
LL	0,61	36,85	0,001	0,70	0,001	0,23
PM	0,50	24,69	0,001	0,57	0,001	0,01

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

The individual lean muscles of traditional cuts comprise only a relatively small percentage of the carcass lean muscle. Most studies on the quality aspects of muscles often use only one or a few muscles of the carcass and the conclusions drawn appear as though the results are representative of the carcass. In the present study 16 muscles of animals of three age groups have been tested for the various tenderness characteristics.

The correlation (in descending order) between the tenderness characteristic obtained for a specific muscle with the mean of the same measurement of all the individual muscles combined are listed in Tables 4.9 to 4.12. Both the model and the slope are significant at the $p \leq 0{,}001$ level. The PM, LL, FDM and ECR have the lowest correlation of all muscles with total carcass sensory analysis of tenderness and residue, as well as resistance to shear force. Shorthose and Harris (1990) listed the LD, GB (in the rump), *gracilis* (in the topside) and PM as showing the lowest correlation of all muscles for all the objective measurements and concluded that these muscles would appear to give the worst indication of the overall carcass tenderness.

TABLE 4.10
Correlation of Sensory Residue of Muscles with the Carcass Sensory Residue Value

Muscle [1]	Correlation coefficient	R-Squared model	p-Value	Std.Err.Est. model	Slope p-value	Intercept p-value
VL	0,79	61,73	0,001	0,46	0,001	0,10
SM	0,78	61,54	0,001	0,48	0,001	0,49
TBCL	0,78	61,09	0,001	0,54	0,001	0,39
ST	0,75	56,31	0,001	0,65	0,001	0,87
GB	0,75	55,97	0,001	0,79	0,001	0,01
SV	0,74	54,67	0,001	0,66	0,001	0,78
OAE	0,73	53,69	0,001	0,65	0,001	0,86
LTW	0,72	52,49	0,001	0,75	0,001	0,42
BC	0,71	50,95	0,001	0,71	0,001	0,39
LTP	0,71	50,42	0,001	0,66	0,001	0,77
PP	0,69	47,35	0,001	0,77	0,001	0,02
FDM	0,67	44,53	0,001	0,60	0,001	0,41
ECR	0,67	44,53	0,001	0,60	0,001	0,41
GM	0,64	40,99	0,001	0,53	0,001	0,01
LL	0,59	35,26	0,001	0,64	0,001	0,11
PM	0,49	23,83	0,001	0,51	0,001	0,01

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

The highest correlation coefficients were obtained for the VL, SM, GB, ST and TBCL for overall carcass sensory analysis of tenderness and residue and for the GB, VL, PP, ST and LTW for resistance to shear force. Shorthose and Harris (1990) also reported the ST, GB and SM as having the highest correlation for the mechanical measurement of overall carcass tenderness. Overall carcass collagen solubility did not follow the same pattern as the sensory tenderness, residue and shear force resistance measurements. It appears as if seven of the muscles/cuts containing the highest collagen solubility (ECR, OAE, SV, TBCL, FDM, BC and VL (Table 4.12) obtained the highest correlation coefficients, although not necessary in the same order.

TABLE 4.11
Correlation of Shear Force of Muscles with the Carcass Shear Force Value

Muscle [1]	Correlation coefficient	R-Squared model	p-Value	Std.Err.Est. model	Slope p-value	Intercept p-value
GB	0,81	66,01	0,001	23,86	0,001	0,01
VL	0,73	53,31	0,001	17,69	0,001	0,49
PP	0,70	48,38	0,001	8,77	0,001	0,43
ST	0,69	48,13	0,001	13,47	0,001	0,05
LTW	0,69	47,20	0,001	2,52	0,001	0,06
OAE	0,68	46,43	0,001	28,14	0,001	0,01
SM	0,67	44,44	0,001	19,20	0,001	0,11
TBCL	0,64	40,58	0,001	16,84	0,001	0,48
GM	0,54	28,87	0,001	15,10	0,001	0,01
SV	0,53	28,47	0,001	16,54	0,001	0,84
LTP	0,47	21,94	0,001	32,14	0,001	0,55
LL	0,45	19,92	0,001	12,63	0,001	0,06
ECR	0,44	19,20	0,001	18,06	0,001	0,55
FDM	0,44	19,20	0,001	18,06	0,001	0,55
PM	0,21	4,52	1,000	12,62	0,100	0,01

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

CONCLUSIONS AND RECOMMENDATIONS

Age did not have any effect on collagen content but collagen solubility showed definite age dependence. In general, tenderness, residue and collagen solubility decreased significantly (although not linearly) with age irrespective of the muscle. Shear force resistance only decreased significantly with age in seven of the 14 cuts. The PM was the most tender muscle, had the least amount of detectable connective tissue residue and the lowest collagen content of all the muscles. The ECR and FDM were the least tender and contained the highest amount of connective tissue (residual and as determined), despite the fact that these muscles contained the most soluble collagen and that they were cooked according to a moist heat cooking method.

TABLE 4.12
Correlation of Collagen Solubility of Cuts/Muscles with the Carcass Collagen Solubility Value

Cut/Muscle [1]	Correlation coefficient	R-Squared model	p-Value	Std.Err.Est. model	Slope p-value	Intercept p-value
Chuck	0,92	85,25	0,001	2,98	0,001	0,07
Thin flank	0,90	80,69	0,001	3,26	0,001	0,53
Hind shin	0,89	79,59	0,001	4,02	0,001	0,76
Neck	0,88	77,78	0,001	3,20	0,001	0,50
Fore shin	0,84	70,32	0,001	4,49	0,001	0,25
VL	0,77	58,96	0,001	4,72	0,001	0,68
TBCL	0,77	58,80	0,001	4,34	0,001	0,23
LL	0,75	56,63	0,001	4,15	0,001	0,95
GM	0,75	55,52	0,001	4,42	0,001	0,54
SM	0,74	54,92	0,001	2,77	0,001	0,47
PP	0,74	54,39	0,001	2,90	0,001	0,11
PM	0,73	53,59	0,001	2,46	0,001	0,01
ST	0,71	50,55	0,001	3,33	0,001	0,14
LTP	0,66	43,58	0,001	3,59	0,001	0,07
GB	0,64	41,09	0,001	3,80	0,001	0,06
LTW	0,63	39,90	0,001	4,95	0,001	0,88

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; PP - *M. pectoralis profundus* and TBCL - *M. triceps brachii caput longum*

However, with the exception of two muscles, they showed the least resistance to shear. This is opposed to the OAE which, although being high in collagen, which was highly soluble, was evaluated by the panel as very tender. An important conclusion is that the results of this study is in agreement with those of Shorthose and Harris (1990) with respect to the representativeness of muscles chosen for the determination of carcass tenderness. In order to determine carcass tenderness in future, the ST and GB (both muscles from the silverside), rather than the PM and the popular LD (LTP, LL and LTW in the present study) should be used.

In conclusion, it can be recommended that as cuts that are grouped together exhibit similar traits, in future only one of these cuts could be used and will be sufficient to describe the group's behaviour for these characteristics. It is proposed that it is not necessary to discriminate between the FDM and ECR cooked as beef retail cuts of 5 cm thickness; that LTW or LTP will sufficiently describe the cuts cooked as intact joints subjected to a dry heat cooking method; and that either GB or TBCL will describe the group subjected to a moist heat cooking method. The LL cooked as beef steak retail cuts and the SV are not included in these groupings. This implies that the 16 cuts could sufficiently be described by six cuts for the tenderness characteristics, which means a great saving in cost and time. These groups were more clearly defined applying CVA rather than PCA - as the variability in such data is large and CVA is more appropriate for well-defined groups. The usual correlation coefficients could not effectively describe the true groupings of similar or dissimilar cuts.

Although age had a significant linear relationship with the different tenderness parameters studied, it is strongly recommended that animals of the B-age group with four and six teeth of the various fatness classes should also be evaluated. The study should be similar in order to determine or quantify the influence of these maturity groups on the different parameters used for describing the tenderness of beef.

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5

Effect of Age and Cuts on Cooking Loss, Juiciness and Flavour of South African Beef

ABSTRACT

The juiciness and flavour characteristics of primal beef cuts from animals of three different age groups were assessed. Fifteen wholesale consumer cuts were obtained from electrically stimulated (500 V) carcasses representing each age group and the full variation in fatness within each age group (n = 61 carcasses). Cooking losses were determined and proximate analyses (percentages total moisture, fat, nitrogen and ash) were performed. Tender cuts (prime rib, wing rib, loin, M. semitendinosus *in the silverside, rump, topside and fillet) were cooked by a dry heat method, and less tender cuts (*M. gluteobiceps *in the silverside, thick flank, chuck, brisket, neck, shoulder, thin flank and the hind and fore shins) were cooked according to a moist heat method at an oven temperature of 160°C, to an internal temperature of 70°C. A trained, ten-member panel, using an eight-point scale evaluated sensory quality characteristics initial and sustained juiciness, aroma and flavour.*

Flavour intensity is the biggest discriminant between the three age groups and it declines with age. The commonly accepted belief that older animals have more flavour than young animals is refuted in this study, as well as the differences between muscles, specifically the PM which is described as relatively lacking in flavour. In general, the initial impression of juiciness decreased with increased age and cooking losses increased (although not linearly) with age, irrespective of the muscle, probably due to a decrease in the ability of the muscle to retain water with increased age. Sustained juiciness increased with increased age, which is explained by the fact that more mastication is required for samples from older animals and therefore more salivation is released, increasing the perceived sustained juiciness.

Cuts cooked according to a dry heat cooking method were juicier (both initial and sustained) than those cooked according to a moist heat cooking method. The PM was not only the juiciest muscle but also had the most intense aroma and flavour compared to all the other muscles. The ECR and FDM were the least juicy and had the least intense flavour.

INTRODUCTION

The results following from a survey (Kingston *et al.* (1987) in Shorthose and Harris (1990)) on consumer preferences for the physical properties of beef loin and topside steaks from animals of different ages (dentition groups), fat classes, gender and breeds, indicated that consumers generally preferred electrically stimulated meat of 0 - 2 tooth animals. Consumers preferred steaks from steers (compared to heifers) for flavour and overall satisfaction. Touraille (1992) found in a consumer (n = 1 000) evaluation study of meat quality criteria that consumers (87%) considered sensory properties to be the most important. The sensory properties of taste, tenderness and aroma were very important, 83%, 78% and 77% respectively, to consumers, compared to 37% for juiciness.

Scheeder and Langholz (1996) found that younger animals scored significantly better in juiciness and texture (tenderness) traits and therefore in acceptance. Horsfield and Taylor (1976) described a system of three independent principal components, namely succulence (which consisted of the following parameters: initial juiciness, breakdown, bolus formation and uniformity), toughness (resistance, resilience and chewiness), and flavour (including off-flavours) which, in that order, contributed to the prediction of acceptability. Risvik (1994) proposed a simple model for texture perception, where juiciness and tenderness were the most important attributes both in terms of description and in terms of preference. In attempting to determine the relative importance of appearance, flavour and texture in perceived quality, Schutz and Wahl (1981) found that 240 respondents scored these attributes for meat and fish products as 2,57, 4,90 and 2,51, respectively. Issanchou (1996) observed in a discussion of recent studies on sensory factors that the importance of tenderness and juiciness appeared to depend on the product and on the consumer, and that the impact of the texture characteristics could have been overestimated while flavour had been underestimated. However, there is no doubt that the sensory characteristics of beef are important to the end-user of meat and it was therefore decided to study juiciness and flavour attributes in this study.

The action and interaction of several ante-mortem and post-mortem factors affect the development of meat flavour. Ante-mortem factors include age, breed, gender and nature of the feed, as well as the nutritional status and composition of the animal. Post-mortem factors include the length of ageing and method of cooking. Of all these factors the final end-point temperature is considered the most important in producing flavour in beef (Spanier & Miller, 1996). Horsfield and Taylor (1976), in studying an extensive range of meat and non-meat alternative products, observed that the more flavour a product had, the more acceptable it was. The flavour of meat is not necessarily a linear function of the fat percentage, and the relationship of meat flavour to preference is not described in the recent literature (Risvik, 1994). However, it is widely accepted that the flavour of food is an important factor in a consumer's purchase decision and that cooking alters the flavour precursors of food to yield a product with a more pleasing taste (Spanier & Miller, 1996).

The sensation of flavour arises from a complex interaction of stimuli activating the taste (sweetness, saltiness, sourness and bitterness), olfactory (smell or odour) and trigemental (general pain and tactile receptors) sensory systems. The flavour of foods is highly dependent on their odour (Key, 1996). The specific aroma of meat is the sensory quality characteristic ascribed to certain volatile substances as perceived by the olfactory organ. The aroma of fresh raw meat intensifies during maturity and exposure to heat (Cross *et al.*, 1986).

Three categories of compounds stand out as particularly important for meat flavour, namely carbonyls, sulphurous compounds and pyrazins. Carbonyls rise from among other lipids, and are therefore found in the volatile compounds of fat and fatty meat. During cooking these carbonyls go through a condensation reaction with amino acids to form cyclic carbonyls. Sulphur is formed from the degradation of the S-containing amino acids in meat protein, and this formation increases with time and the temperature of cooking. Compounds like sugars and S-containing amino acids form thiols, which possess meaty flavours. Pyrazins are only formed during the heating of meat (significant only from 70°C) and are generally found in the browned surface of the meat (Smulders *et al.*, 1991).

Dry or moist heat cooking methods refer to the atmosphere surrounding the meat. The influence exerted by the cooking method usually depends on the rate at which heat energy is supplied to the external surface, and on the end-point cooking temperature. During moist heat cooking the temperature of the water vapour will not exceed 100°C, which is considerably lower than the temperature to which the external surface of the meat is exposed during dry heat cooking. The rate at which the interior of meat is heated includes, and is not limited to, the rate and intensity at which energy is transmitted to the meat, the shape and size of the sample being heated, the composition of the sample, the spatial distribution of areas of lean, fat, connective tissue and bones, the characteristics of the meat surface, and any changes induced in the meat by heat, including protein denaturation, loss of water and the melting of fat (Seideman & Durland, 1984). Ferger *et al.* (1972) stated that there is little difference between dry and moist heat cooking methods in terms of cooking time, percentage total cooking loss, flavour, juiciness and tenderness. According to Honikel (1988) meat may lose as much as 40% of its juice during cooking, with a steady increase from 50°C to 90°C in the end-point temperature.

The relationship of beef flavour and juiciness to particular muscles and animal age, as defined by dentition, has never been investigated in the South African context, even though age is one of the two variables (the other being carcass fat cover) included in the South African beef carcass classification system. In order to make meaningful recommendations to the consumer, it was decided to investigate these aspects. As overall lean-meat aroma (Wasserman & Talley, 1968) and flavour are not determined by the degree of fatness (Patterson, 1975), this variable as such was not investigated. The objective of this study was therefore to determine the effect of age on cooking, juiciness and flavour related quality characteristics of seven and eight primal cuts of beef, cooked according to a dry and a moist heat method respectively, from beef animals of three different age groups (statistically analysed with carcass fat content as a covariant, to adjust for initial differences in carcass fat content).

As the beef carcass classification system in South Africa is a dynamic system and therefore changes according to consumer demand, it would be useful to develop statistical models that could adapt to changes in the age groupings. Therefore a second objective, namely the prediction of juiciness characteristics for the various age groups, was identified.

MATERIALS AND METHODS

Source of materials

The beef carcasses (*n* = 61) used in this study had a mass range of 190 kg to 240 kg. No specific breed was chosen. Only steers and heifers were selected due to the small proportion of bull carcasses presently on the market in South Africa. The three age groups were A (no permanent incisors), B (2 or more permanent incisors) and C (≥8-toothed). Due to the fact that carcass fatness could influence (but not determine according to Patterson, 1975) juiciness and flavour, carcasses representing the full spectrum within each age group were selected. Please refer to Table 5.1 for a schematic diagram of the research design.

TABLE 5.1
Experimental Design to Determine Sensory and Cooking Characteristics of Beef Carcasses

Age group			**Total number of carcasses**
A	B	C	
21	20	20	61

The carcasses were obtained on the commercial market (at the largest abattoir in the country) and had been selected by qualified classifiers. They were electrically stimulated (500 V) within 10 minutes of stunning, dressed, halved, chilled overnight at between 0°C and 5°C, labelled and transported to the ARC-ANPI in a refrigerated truck.

Sample preparation

Each of the right sides of beef was subdivided into 15 wholesale cuts to determine its physical composition and for chemical analysis (Figure 5.1). This involved subdivision of the cuts into subcutaneous fat, meat and bone. The subcutaneous fat plus meat were cubed, thoroughly mixed and then minced, first through a 5 mm and then through a 2 mm mesh plate. A representative sample of 300 g of the subcutaneous fat plus meat tissue obtained from each cut was analysed to determine the percentages of total moisture (oven-dry method), fat (Soxhlet extraction with diethyl ether for 16 hours), nitrogen (Kjeldahl-method using a Büchi 430 block digester and a Büchi 322 distilatlion unit) (N *x* 6,25 = protein) and ash (by ignition at 800°C). Moisture and fat content of samples were determined in triplicate and protein content was determined in duplicate. If the sum of the proximate values did not meet 100±1,5% samples were reanalysed. These determinations were performed according to AOAC methods (1995). The chemical analysis results were combined with the subcutaneous fat and meat (muscle and inter- and intramuscular fat) content results obtained from the physical dissections for the calculation of muscle and total fat content of each specific cut, expressed as a percentage of carcass mass (Carroll & Conniffe, 1967).

16 = Silverside (*M. semitendinosus* (ST))
15 = Hind shin (*M. flexor digitorum medialis* (FDM))
14 = Topside (*M. semimembranosus* (SM))
13 = Silverside (*M. gluteobiceps* (GB))
12 = Thick flank (*M. vastus lateralis* (VL))
11 = Fillet (*M. psoas major* (PM))
10 = Rump (*M. gluteus medius* (GM))
9 = Thin flank (*M. obliques abdominus externus* (OAE))
8 = Loin (*M. longissimus lumborum* (LL))
7 = Wing rib (*M. longissimus thoracis* (LTW))
6 = Prime rib (*M. longissimus thoracis* (LTP))
5 = Brisket (*M. pectoralis profundus* (PP))
4 = Chuck (*M. serratus ventralis* (SV))
3 = Shoulder (*M. triceps brachii caput longum* (TBCL))
2 = Fore shin (*M. extensor carpi radialis* (ECR))
1 = Neck (*M. biventer cervicis* (BC))

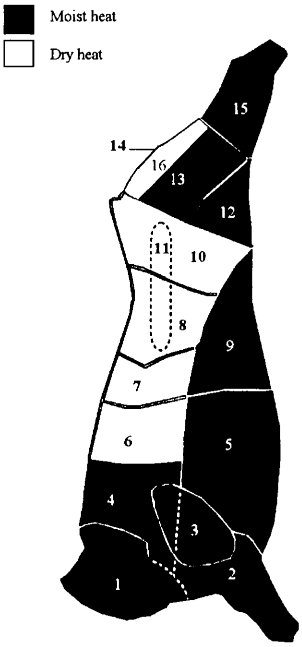

Fig. 5.1: Wholesale cut from the carcass

Sixty-one left sides were used to determine cooking losses and sensory analysis. The left sides were portioned into 15 wholesale cuts with the rump and topside deboned. The cuts were then vacuum-packed, aged at 4°C for 10 days post-slaughter and then stored at -40°C prior to cooking and sensory analysis. The cuts were defrosted at 6°C to 8°C for periods varying between 24 and 36 hours (depending on mass), until the internal temperature reached 2°C to 5°C (American Meat Science Association (AMSA), 1978). During the various pilot studies it became clear that the internal temperature of certain muscles, e.g. *M. semimembranosus,* differed considerably from that of the rest of the topside cut due to its anatomical position. It was therefore decided to measure only the internal temperature of the particular muscle to be evaluated, which was the largest in each cut. A J-type thermocouple placed in the geometric centre of each muscle to be evaluated, linked to a centrally controlled computer system, was used to record internal temperature. A hand-model Kane-Mane probe equipped with a T-type thermocouple was used to check the final temperature (70°C) of the cut prior to removal from the oven.

Cooking methods

Dry heat cooking method

The following cuts (*muscles*) were used: prime rib - 8th to 10th rib (*M. longissimus thoracis* (LTP)); loin (*M. longissimus lumborum* (LL)); wing rib - 11th to 13th rib (*M. longissimus thoracis* (LTW)); rump (*M. gluteus medius* (GM)); topside (*M. semimembranosus* (SM)); silverside (*M. semitendinosus* (ST)) and fillet (*M. psoas major* (PM)) (Nomina Anatomica Veterinaria, 1983). All these cuts, excluding the loin, were cooked in their primal form. The cuts were roasted whole at 160°C, on a rack in an open oven pan, until the muscle to be evaluated had reached an internal temperature of 70°C. The loin cuts were portioned into 25 mm thick steaks (AMSA, 1978), vacuum-packed and stored at -40°C. The defrosted steaks were cooked according to an oven-broiling method (on a rack) where the meat is cooked by direct radiant heat (> 200°C) to an internal temperature of 70°C.

Moist heat cooking

The following cuts (muscles) were used: silverside (*M. gluteobiceps* (GB)); thick flank (*M. vastus lateralis* (VL)); chuck (*M. serratus ventralis* (SV)); brisket (*M. pectoralis profundus* (PP)); neck (*M. biventer cervicis* (BC)); shoulder (*M. triceps brachii caput longum* (TBCL)); thin flank (*M. obliquus abdominis externus* (OAE)) and shins (*M. extensor carpi radialis* (ECR) and *M. flexor digitorum medialis* (FDM)) (Nomina Anatomica Veterinaria, 1983). The silverside, thick flank, chuck, shoulder and neck were cooked in primal form. The brisket and thin flank were formed into a meat roll and covered with mesh before ageing. Prior to cooking the frozen fore and hind shins were portioned into 5 cm thick cuts. All cuts were broiled at 160°C on a rack in a covered stainless steel casserole dish until the muscle to be evaluated reached an internal temperature of 70°C. Distilled water (100 ml) at room temperature was added to each dish before cooking commenced.

All the cuts (dry and moist) were kept at room temperature for a standing period of 10 minutes after cooking. The different muscles were then dissected and halved for sensory analysis and were immediately cut up. Ten cubed samples were taken from the middle of each muscle and immediately individually wrapped in foil marked with random three-digit codes. These samples were served at an internal temperature of 60°C within 30 minutes after removing the whole cut from the oven. A 100 g sample of the cooked muscle was analysed according to AOAC methods (1995) to determine the percentages of total moisture, fat and nitrogen (N *x* 6,25 = protein).

In order to compare age effects, the sensory panel was presented with samples of identical muscle from the three age groups with comparable fatness levels (therefore comparable marbling and similar impregnation of subcutaneous fat into the muscle during cooking). Samples were tasted at each of the 20 sessions on seven consecutive working days, with the order of the age groups randomised for each session. Cooking and sensory analyses were then performed on the subsequent cuts without any particular order of cooking for the various cuts (3 samples *x* 20 sessions *x* 15 cuts = 900 samples tasted) over a period of seven months.

Data recorded during the study

Total cooking losses

All the cuts were weighed pre- and post-thawing to determine thawing loss, as well as pre- and post-cooking. Total cooking and drip losses were calculated, using the initial (pre-cooking) and final total mass (post-cooking) of each cut and the volume of drippings from each sample expressed as mass. Evaporation losses were then calculated as the difference between the total cooking loss and drip losses (AMSA, 1978). Evaporation, drip and total cooking loss were expressed as a percentage of the initial raw mass.

Descriptive palatability attributes

A ten-member, trained, descriptive sensory panel was used to evaluate the palatability attributes of each cut. Panellists were selected and trained over a two-month period in accordance with the AMSA Guidelines for Cooking and Sensory Evaluation of Meat (AMSA, 1978) and the procedures of Cross *et al.* (1978). Reliability and validity of the sensory results were used as criteria for selecting members. Panellists, seated in individual booths in a temperature-controlled room, received a set of three samples, wrapped and marked with randomly selected three digit codes. The colour of the samples was masked by the use of red light. Samples (1 cm^3) were evaluated on an 8-point scale (1 denoting the least favourable and 8 the most favourable condition) for aroma (volatile substances perceptible to the olfactory organ), initial juiciness (amount of fluid on the cut surface when pressed between thumb and forefinger), sustained juiciness (impression of juiciness as panellists started chewing) and flavour (combination of taste while chewing and swallowing). Distilled water at room temperature was used to cleanse the palate between samples.

STATISTICAL ANALYSIS

Although principal component analyses (PCA) (GENSTAT 5, 1996) were performed on all the variates for each of the 15 cuts, the results are not presented due to limited space ($n = 7$ juiciness and flavour parameters x 15 cuts = 105 plots). However, fatness of the carcass was identified as one of the most important gradients in this multivariate data space (data matrix). It was therefore decided to include fatness of the carcass as a covariant in a PROC GLM procedure (SAS, 1996) for the analyses of variance performed on the data. According to Schlich (1996), sensory scientists appear to have overlooked canonical variate analysis (CVA) in favour of PCA. However, PCA is limited by the fact that all attributes having product means not significantly different from each other, which is stated by means of an analysis of variance (ANOVA), has the same weight as a discriminant attribute of the products. Although this can be overcome by including only attributes that are significant for the product effect, a more appropriate method would be CVA.

CVA (GENSTAT 5, 1996), also known as linear discriminant analysis, was therefore used to determine groupings in the different age groups (A, B and C) and/or the 15 cuts. In this study the variates were the aroma, flavour, juiciness and cooking losses that were measured for each cut. The scores found for each of the canonical variates were then correlated with the original variates to establish which were the most important in discriminating between the age groups and/or cuts (Digby & Kempthorne, 1987). The logarithms of the variates were used to stabilise the variances.

As only the directions of the main variability in the data matrix are attended to in these analyses, the more subtle sources of variation were investigated by ANOVA (SAS, 1996) as proposed by Næs *et al.* (1996). A correlation matrix was constructed to test for correlation between the different variables. To ensure that the effect of animal age was determined and not the effect of fatness of the carcass, the total fat content of the carcass (as determined by proximate analyses for the 15 wholesale cuts and calculated for the carcass according to the relative mass of each cut) was used as covariant (*X*), both as natural *X* and $X^{2,}$ in a PROC GLM (SAS, 1996) procedure. In searching for the most simplistic model the covariant was removed from the model if not significant (very generously at $p \geq 0{,}15$), starting with X^2 and continuing with *X*. Separation of the mean scores for interaction of the different variables for the various cuts from the three age groups was achieved by the application of Tukey's method (SAS, 1996).

In order to attain the second objective, namely the prediction of the juiciness of the cuts from the various age groups, regression equations ($Y = A + BX$) were used for the main model. In the regression equation the age of the animal (*X*) was tested against the various characteristics (*Y*) of each cut and of the entire carcass. As most of the data were not normally distributed, the dependent variates in the equation (*Y*) were transformed to Y^2, Y^3, $\sqrt{Y}$ and *ln Y* (natural log). These four transformations, together with the natural *Y*, were combined in forward stepwise regression analyses and tested against juiciness as analysed by the taste panel. However, these models should be of a certain accuracy to obtain repeatable and reliable predictions of carcass and cut juiciness. The accuracy of such models is determined by the R^2 (percentage variation) and the residual standard deviation or RSD (error variance around the regression line). As very few of the R^2 values were ≥ 50% this was not considered a reliable method of predicting juiciness in meat. The data were therefore studied by analyses of variance for the three age groups as described above, where the R^2 and p-value of the model are also presented. It was again found not to be a reliable method for predicting juiciness. Therefore no satisfactory statistical model was identified within the scope of this study for the accurate prediction of juiciness of the meat of animals in different age groups.

Cuts were ranked in descending order according to the percentage thawing, evaporation, drip and total cooking loss, as well as according to sensory evaluation scores. These were summarised in tabels.

RESULTS AND DISCUSSION

Effect of age on cooking, juiciness and flavour

Please note that the cuts were cooked, but that the attribute panel tasted individual muscles. The results of the canonical variate analyses showed that the first canonical variate (CV1) accounted for 84,7% of the total variation in the data but that the latent root was less than 1 (0,0494), therefore the results cannot be taken too seriously. The canonical variate means for thawing loss, aroma, flavour, initial impression of juiciness and sustained juiciness were positive and negative for all the cooking losses, thus CV1 clearly contrasts between these variables. The main discriminant attribute was flavour (r = 0,600) as it correlated the strongest with the CV scores on the CV1 axis (horisontal).

The dimensional graphic presentation of the series highlights the ordination and/or grouping of similar ages (points close together are similar and those far apart dissimilar). The CV mean scores are presented in Figure 5.2. Flavour intensity is the largest discriminant in the three age groups and it declines with age. These results are probably due to changes in the amino acid, protein and nucleotide metabolism (Smulders *et al.*, 1991) with increased animal age. According to Sink (1979), age affects the "water-soluble, meaty" aspect more than the "lipid-soluble, species-specific" flavour. The decline in flavour with age corresponds with the findings of Cross *et al.* (1973b) who found that flavour ratings were highest for steaks in the A (very young) maturity group, compared to the C to E (older) maturity groups.

For the analyses of variance (ANOVA), the chemical analysis data were combined with the subcutaneous fat, meat (muscle and intermuscular fat) and bone content results obtained from the physical dissections for the calculation of percentages of meat, total fat and bone content of each specific cut (Carroll & Conniffe, 1967). These values were summed to obtain the chemical (fat, protein and moisture) and physical (meat, total fat and bone) composition of the carcass. This percentage total fat content of the carcass was used as a covariant in the PROC GLM procedure to adjust for differences between initial fat content and was 15,74% with a minimum of 8,03% and a maximum of 29,75%. The following other fat attributes were measured for this data set:

- Subcutaneous fat (%) of the carcass: mean = 6,21; minimum = 1,17; maximum = 13,36

- Proximate fat (%) in the carcass: mean = 13,46; minimum = 1,61; maximum = 42,89
- Proximate fat (%) in the cooked muscles: mean = 4,93; minimum = 0,98; maximum = 26,61.

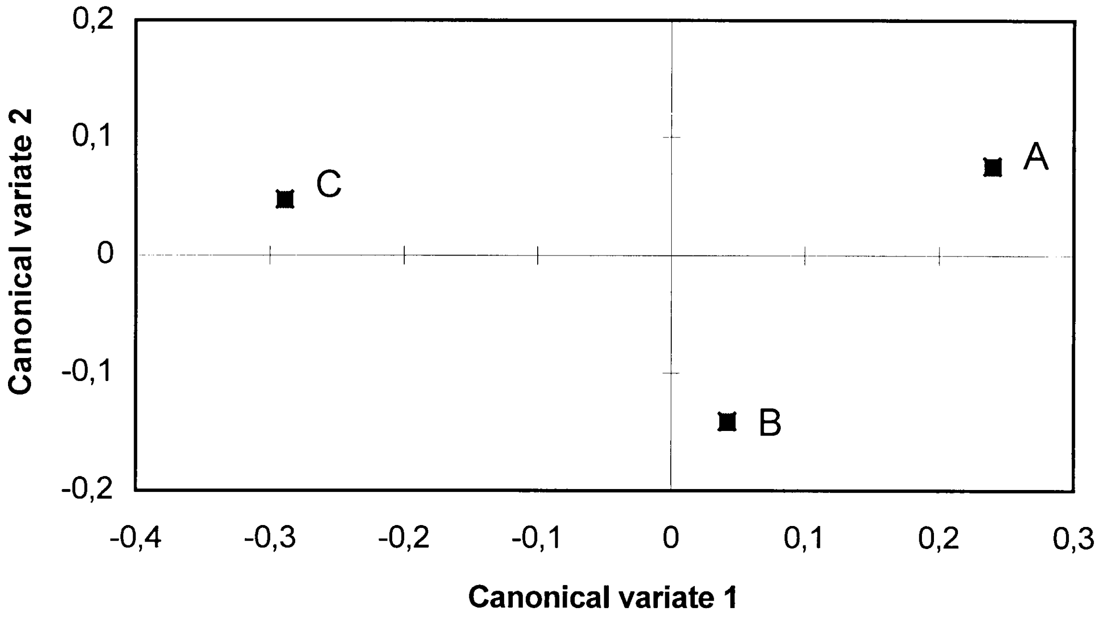

Fig. 5.2: Plot of CV mean scores of three age groups[1]

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

As shown in Table 5.2 the age of the animal did not show a consistently significant effect on thawing loss, although when significant (p ≤ 0,05), thawing loss decreased with increased animal age (prime rib, wing rib and GB). The age of the animal did not have a marked influence on evaporation loss although it increased with increased age of the animal in the wing rib and decreased with increased age in the thin flank. The drip loss showed an age effect in only two of the 15 cuts with a significant (p ≤ 0,05) increase with increased age in the wing rib and thin flank and a decrease with increased age in the topside of the B-and C-age groups. The total cooking loss showed a significant (p ≤ 0,05) difference in seven of the 15 cuts that were cooked. The total cooking loss for the prime rib, wing rib, rump and topside of the A-age group was significantly (p ≤ 0,05) less than that of the B-age group. The total cooking loss of the prime rib and wing rib of the B-age group was significantly (p ≤ 0,05) less than that of the C-age group. The GB, shoulder and thin flank of the A-age group showed significantly (p ≤ 0,05) less total cooking loss than the cuts from the C-age group.

TABLE 5.2

Least Square Mean (± Standard Error of Mean) Values of Thawing and Cooking Losses for Cuts Obtained From Three Age Groups (Average Chemical Fat of the Carcass used as Covariant[1] = 15,74 %)

Cut	Model		Covariant[1]			Age						
							A		B		C	
	R^2 %	p-Value	Raw mass of cut	X p-Value	X^2 p-Value	Age p-Value	Mean	SEM	Mean	SEM	Mean	SEM
Thawing Loss (%) Cooked (Dry Heat)												
Prime rib	19	0,0192	0,8644	0,0707		0,0228	1,02^{a}	0,182	0,81^{ab}	0,187	0,31^{b}	0,178
Loin	22	0,0073	0,0846	0,0013		0,2679	0,29	0,079	0,31	0,083	0,14	0,079
Wing rib	25	0,0024	0,6963	0,0197		0,0107	0,88^{a}	0,147	0,78^{a}	0,154	0,27^{b}	0,147
Silverside[2]	21	0,0108	0,0821	0,0026		0,1254	4,90	0,374	4,47	0,393	3,81	0,375
Rump	14	0,0313	0,0055			0,8952	2,21	0,449	2,52	0,463	2,36	0,460
Topside	21	0,0040	0,0056			0,3887	0,45	0,080	0,38	0,085	0,29	0,083
Fillet	8	0,1710	0,0700			0,2948	3,04	0,573	4,36	0,615	3,51	0,583
Cooked (Moist Heat)												
Silverside[3]	27	0,0012	0,1489	0,0164		0,0016	6,15^{a}	0,456	5,21^{ab}	0,470	3,67^{b}	0,469
Thick flank	6	0,4880	0,6041	0,0798		0,8028	1,17	0,216	0,96	0,226	1,03	0,212
Chuck	20	0,0294	0,1779	0,0496	0,0979	0,4555	0,91	0,349	1,40	0,339	0,85	0,350
Brisket	20	0,0054	0,0046			0,4618	0,89	0,172	0,58	0,185	0,68	0,172
Neck	10	0,2260	0,7155	0,1118		0,2453	0,63	0,143	0,41	0,155	0,30	0,142
Shoulder	20	0,0049	0,0007			0,6128	3,34	0,532	3,80	0,574	3,01	0,567
Thin flank	20	0,0249	0,0130	0,1066	0,1147	0,1719	0,91	0,171	0,78	0,179	0,46	0,171
Shins	39	0,0001	0,0001	0,0281	0,0452	0,2432	0,84	0,205	1,30	0,204	1,24	0,202
Evaporation Loss (%) Cooked (Dry Heat)												
Prime rib	33	0,0005	0,0544	0,1891	0,0909	0,3269	19,76	0,347	20,10	0,357	20,49	0,338
Loin	27	0,0042	0,8232	0,0002	0,0003	0,1591	15,38	1,064	17,32	1,192	14,20	1,057
Wing rib	36	0,0001	0,5434	0,0001		0,0456	16,49^{a}	0,438	16,87^{a}	0,459	18,06^{b}	0,460
Silverside[2]	13	0,1056	0,7217	0,0150		0,7051	19,55	0,670	19,13	0,706	19,94	0,656
Rump	35	0,0002	0,2728	0,0311	0,1236	0,0747	27,02	0,666	29,15	0,673	28,68	0,672
Topside	23	0,0066	0,0007	0,0505		0,3100	20,80	0,895	22,42	0,914	22,63	0,889
Fillet	0,3	0,9832	0,9221			0,9259	21,54	0,706	21,66	0,758	21,26	0,718
Cooked (Moist Heat)												
Silverside[3]	14	0,0353	0,0094			0,5693	5,83	0,429	5,27	0,452	5,88	0,451
Thick flank	17	0,0664	0,0436	0,0236	0,0491	0,3141	9,61	0,476	10,24	0,496	10,65	0,477
Chuck	22	0,0066	0,0754	0,0590		0,6623	2,38	0,349	2,72	0,340	2,84	0,351
Brisket	5	0,6177	0,8814	0,1156		0,9153	8,85	0,618	9,01	0,651	9,22	0,605
Neck	4	0,4802	0,1509			0,8466	9,32	0,678	9,24	0,759	8,80	0,675
Shoulder	26	0,0007	0,0013			0,1111	10,61	0,718	10,19	0,755	12,32	0,747
Thin flank	22	0,0075	0,3285	0,0305		0,0170	11,17^{a}	0,539	9,14^{b}	0,555	9,30^{b}	0,529
Shins	25	0,0024	0,0011	0,1114		0,4672	1,01	0,166	1,28	0,165	1,06	0,164

[1] p-values of the full model, if not significant (p ≥ 0,15) covariant was removed from the model starting with X^2 and continuing with X

[2] Silverside: ST - *M. semitendinosus*; [3] Silverside: GB - *M. gluteobiceps*

[abc] Means in the same row with different superscripts differ significantly (p ≤ 0,05)

TABLE 5.2 CONT.

Least Square Mean Values (± Standard Error of Mean) of Thawing and Cooking Losses for Cuts Obtained From Three Age Groups (Average Chemical Fat of the Carcass used as Covariant[1] = 15,74 %)

Cut	Model		Covariant[1]			Age						
							A		B		C	
	R^2 %	p-Value	Raw mass of cut	X p-Value	X^2 p-Value	Age p-Value	Mean	SEM	Mean	SEM	Mean	SEM
Drip Loss (%) Cooked (Dry Heat)												
Prime rib	68	0,0001	0,0349	0,0001		0,0001	4,76	0,336	6,11	0,345	7,79	0,329
Loin	29	0,0018	0,2351	0,0006	0,0026	0,5423	9,64	0,463	8,90	0,489	9,43	0,460
Wing rib	79	0,0001	0,0003	0,0001		0,0001	6,18^{a}	0,401	7,80^{b}	0,420	10,69^{c}	0,420
Silverside[2]	11	0,1740	0,2701	0,0270		0,4806	5,01	0,361	4,63	0,379	5,26	0,362
Rump	54	0,0001	0,0010	0,0014	0,0066	0,0901	10,09	0,483	10,57	0,489	11,66	0,488
Topside	15	0,0318	0,0458			0,0437	15,14^{ab}	0,636	15,99^{a}	0,677	13,56^{b}	0,679
Fillet	28	0,0003	0,0001			0,1440	5,94	0,451	4,81	0,484	6,01	0,458
Cooked (Moist Heat)												
Silverside[3]	18	0,0542	0,4627	0,0283	0,0208	0,1071	23,96	0,598	24,73	0,618	25,80	0,613
Thick flank	15	0,1197	0,3930	0,0472	0,0817	0,9787	28,80	0,591	28,63	0,617	28,68	0,593
Chuck	11	0,2650	0,8855	0,2187	0,1211	0,9606	31,42	0,847	31,62	0,823	31,30	0,849
Brisket	7	0,3937	0,6556	0,0967		0,4610	22,65	1,317	21,72	1,386	24,05	1,287
Neck	44	0,0001	0,0001	0,2328	0,1122	0,2831	19,50	1,072	21,64	1,172	21,63	1,039
Shoulder	3	0,6385	0,4778			0,4640	17,89	1,268	19,12	1,333	20,22	1,319
Thin flank	47	0,0001	0,1227	0,2339	0,0571	0,0001	14,45^{a}	0,666	17,75^{b}	0,699	18,56^{b}	0,666
Shins	46	0,0001	0,0009	0,0001	0,0001	0,1257	21,32	0,687	19,87	0,684	19,27	0,678
Total Cooking Loss (%) Cooked (Dry Heat)												
Prime rib	44	0,0001	0,8676	0,0303	0,0907	0,0001	24,54^{a}	0,497	26,18^{b}	0,511	28,28^{c}	0,484
Loin	15	0,1093	0,3367	0,0268	0,0206	0,3792	25,04	1,055	25,84	1,181	23,67	1,048
Wing rib	55	0,0001	0,0082	0,0969		0,0001	22,66^{a}	0,657	24,67^{b}	0,688	28,75^{c}	0,689
Silverside[2]	6	0,3525	0,2525			0,3406	24,30	0,792	23,55	0,854	25,27	0,792
Rump	30	0,0004	0,1248	0,1327		0,0029	37,10^{a}	0,651	39,75^{b}	0,656	40,32^{b}	0,656
Topside	22	0,0092	0,0163	0,0722		0,0298	35,75^{a}	0,709	38,39^{b}	0,723	36,35^{a}	0,723
Fillet	12	0,0653	0,0097			0,6134	27,48	0,719	26,47	0,772	27,27	0,731
Cooked (Moist Heat)												
Silverside[3]	29	0,0020	0,0047	0,0258	0,0181	0,0448	29,86^{a}	0,547	30,00^{a}	0,565	31,68^{b}	0,560
Thick flank	21	0,0036	0,0004			0,2575	38,34	0,416	38,89	0,442	39,35	0,430
Chuck	9	0,3697	0,5207	0,0908	0,0599	0,9102	33,83	0,821	34,32	0,797	34,12	0,824
Brisket	12	0,1222	0,6003	0,0165		0,3737	31,51	1,300	30,73	1,368	33,27	1,271
Neck	38	0,0001	0,0001	0,0535		0,3062	28,91	0,940	30,93	1,028	30,49	0,913
Shoulder	16	0,0187	0,1834			0,0440	28,50^{a}	1,129	29,31^{a}	1,187	32,54^{b}	1,174
Thin flank	25	0,0065	0,3371	0,2189	0,0924	0,0492	25,59^{a}	0,649	26,90^{ab}	0,666	27,88^{b}	0,633
Shins	47	0,0001	0,0002	0,0001	0,0001	0,1944	22,34	0,748	21,14	0,745	20,33	0,738

[1] p-values of the full model; if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

[2] Silverside: ST - *M. semitendinosus*; [3] Silverside: GB - *M. gluteobiceps*

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 5.3

Least Square Mean Values (± Standard Error of Mean) of Aroma and Flavour for Muscles Obtained From Three Age Groups (Average Chemical Fat of the Carcass used as Covariant = 15,74 %)

Muscle[1]	Model		Co-variant[2]		Age						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
Aroma (8=extremely intense;1=extremely bland): Cooked (Dry Heat)											
LTP	5	0,0001	0,0389	0,1246	0,0009	$5,72^{a}$	0,081	$5,59^{a}$	0,083	$5,30^{b}$	0,078
LL	1	0,0360			0,0360	$5,55^{a}$	0,066	$5,79^{b}$	0,071	$5,71^{ab}$	0,068
LTW	1	0,0960	0,0772	0,1048	0,1598	5,89	0,076	5,75	0,080	5,69	0,076
ST	0,9	0,2568	0,0658	0,0915	0,3933	5,88	0,061	6,00	0,064	5,93	0,061
GM	1	0,0838	0,0078	0,0140	0,9661	5,96	0,071	5,98	0,074	5,96	0,070
SM	3	0,0029	0,0031	0,0105	0,4992	6,13	0,056	6,04	0,061	6,09	0,058
PM	0,5	0,2249			0,2249	6,19	0,058	6,28	0,063	6,33	0,060
Cooked (Moist Heat)											
GB	0,7	0,2128	0,0383		0,8967	6,10	0,065	6,07	0,068	6,06	0,065
VL	0,3	0,4466			0,4466	6,10	0,057	6,12	0,061	6,02	0,058
SV	3	0,0006	0,0032	0,0148	0,0344	$5,88^{a}$	0,065	$6,07^{b}$	0,069	$5,84^{a}$	0,065
PP	1	0,1656	0,0336	0,0344	0,2680	5,49	0,076	5,66	0,080	5,61	0,078
BC	1	0,0613	0,0794		0,1505	5,89	0,076	5,84	0,082	5,69	0,076
TBCL	1	0,2039	0,0692	0,0712	0,1913	5,55	0,080	5,88	0,084	5,78	0,080
OAC	0,7	0,3611	0,1118	0,1239	0,3474	5,53	0,075	5,65	0,079	5,68	0,075
ECR&FDM	2	0,0151	0,0671	0,0236	0,6058	5,92	0,073	5,84	0,077	5,95	0,073
Flavour (8=extremely intense;1=extremely bland): Cooked (Dry Heat)											
LTP	0,9	0,1556	0,0318		0,7926	5,48	0,083	5,44	0,085	5,40	0,081
LL	7	0,0001	0,0001		0,0410	$5,34^{a}$	0,068	$5,39^{ab}$	0,071	$5,57^{b}$	0,068
LTW	2	0,0280	0,0234		0,1597	5,78	0,083	5,65	0,088	5,55	0,084
ST	1	0,0727	0,0183		0,5455	5,72	0,060	5,66	0,063	5,62	0,60
GM	3	0,0015	0,0011		0,1469	5,67	0,068	5,65	0,072	5,49	0,068
SM	0,2	0,5132			0,5132	5,54	0,052	5,49	0,057	5,46	0,054
PM	1	0,1099	0,0176	0,0149	0,3677	6,17	0,060	6,24	0,063	6,29	0,060
Cooked (Moist Heat)											
GB	2	0,0374	0,0387	0,0285	0,0536	$5,65^{a}$	0,063	$5,53^{ab}$	0,066	$5,44^{b}$	0,063
VL	2	0,0155	0,0905		0,0306	$5,68^{a}$	0,056	$5,64^{ab}$	0,059	$5,48^{b}$	0,056
SV	2	0,0006			0,0006	$5,71^{a}$	0,072	$5,66^{a}$	0,077	$5,34^{b}$	0,073
PP	4	0,0001	0,0733		0,0002	$5,36^{a}$	0,086	$5,36^{a}$	0,091	$4,91^{b}$	0,089
BC	1	0,1012	0,0964		0,2256	5,96	0,087	5,94	0,094	5,76	0,087
TBCL	2	0,0077	0,0006		0,9204	5,72	0,078	5,70	0,082	5,74	0,078
OAE	1	0,0333			0,0333	$5,89^{a}$	0,078	$5,96^{a}$	0,084	$5,67^{b}$	0,080
ECR&FDM	0,4	0,3393			0,3393	5,03	0,105	5,16	0,113	4,93	0,108

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] p-values of the full model; if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

These results were obtained irrespective of the fact that there was no significant difference between the various fat parameters measured for the three age groups and that the raw mass of the cut was included as a covariant. This suggests that the muscle or protein denatures with animal age, resulting in increased moisture loss upon heating or cooking irrespective of whether dry or moist heat is used, although it could be argued that dry heat had a more pronounced effect. According to Rasmussen and Anderson (1996), moisture loss is a reflection of the inability of meat to hold the natural meat juices in the muscle and muscle fibres. A high loss might be due to both increased denaturation of the protein with age, or increased cross-linking of collagen with age, resulting in decreased water holding capacity (Boccard, 1973). Tuma *et al.* (1963) also reported a significant ($p \leq 0{,}01$) decrease in moisture content due to increased animal age.

The age of the animal (Table 5.3) showed a significant ($p \leq 0{,}05$) effect on aroma intensity in three of the 15 cuts that were evaluated. There was a significant ($p \leq 0{,}01$) difference in aroma intensity in the LTP of the A-age group and that of the same muscle in the C-age group, with aroma intensity decreasing with increased age. The aroma was significantly ($p \leq 0{,}01$) more intense in the LL and SV of the B-age group than in the same cuts from animals of the A-age group.

According to Table 5.3, flavour intensity increased significantly ($p \leq 0{,}05$) with increased age in only one of the seven cuts cooked by a dry heat cooking method, namely the LL. Contrary to general belief (Sink & Caporaso, 1977; Ford & Park, 1987)), flavour intensity decreased significantly ($p \leq 0{,}05$) with increased age in five of the eight cuts cooked by a moist heat cooking method. The flavour of the GB, VL, SV, PP and OAE from the A-age group was significantly ($p \leq 0{,}05$) more intense than in the same cuts from the C-age group.

It is therefore concluded that the age of the animals did not have a constantly significant effect on the aroma intensity of the 15 cuts that were studied, and flavour intensity increased in only one of the cuts cooked according to a dry heat cooking method. However, the cuts cooked according to a moist heat cooking method showed a decrease in flavour intensity with increased age in five of the eight cuts. According to Tuma *et al.* (1963), more flavourful meat is normally associated with older animals, although they also found an insignificant decline in flavour with increased animal age from 6 to 90 months. The fact that this difference in flavour intensity was found in the cuts cooked by a moist heat cooking method and not in those cooked by a dry heat cooking method, is ascribed to the presence of moisture in the production or liberation of cooked beef flavour compounds (Mac Leod & Ames, 1987; Ford & Park, 1987).

Although the juiciness of meat was generally expected to decrease with increased animal age (at an equal fatness level), this was not found in this study (Table 5.4). In all seven of the cuts cooked by a dry heat cooking method, the only significant difference ($p \leq 0{,}05$) in the initial impression of juiciness was found in the LL. The initial impression of juiciness of the LL of the B-age group was significantly ($p \leq 0{,}05$) lower than in the LL from the A-and C-age groups. The initial impression and sustained of juiciness of the PP and BC (cooked by a moist heat cooking method) of the A-age group was significantly ($p \leq 0{,}05$) higher than in the same cuts from the C-age group. The initial impression of juiciness of the VL of the A- and B-age groups was significantly ($p \leq 0{,}05$) higher than for the C-age group. The initial and sustained juiciness of the ECR and FDM of the A-age group was significantly ($p \leq 0{,}05$) more noticeable than in the same cuts from the B-age group. Contrary to the expectation that juiciness generally decreases with age, the sustained juiciness of the ST, PM, GB and OAE of the C-age group was significantly ($p \leq 0{,}05$) higher than for the A-age group. The PM, VL, SV, and OAE of the B-age group was significantly ($p \leq 0{,}05$) more juicy than the same cuts from the A-age group. The sustained juiciness of the TBCL of the B-age group was significantly ($p \leq 0{,}05$) more noticeable than in the same cuts from the C-age group. In general, initial juiciness appears to decrease with increased animal age, and sustained juiciness seems to increase with increased animal age. This finding should be further investigated, possibly with the inclusion of the determination of ultimate pH and the measurement of sarcomere lengths.

Since the influence of fat was taken as a covariant in this study, the major contributor to the sensation of juiciness was the moisture remaining in the cooked product. As the fat-free water content of meat is relatively uniform, differences in juiciness have to relate to the ability of the muscle to retain water during cooking (Forrest *et. al.*, 1975). The decrease in initial juiciness with increased animal age could be attributed to the fact that this ability of the muscle to retain water decreased with increased age, with consequently higher cooking losses in cuts from older animals. This is associated with a drier end product, without the rapid release of meat fluid during the first few chews as was found in the meat from young animals.

The result that sustained juiciness increased with increased age may be explained by the fact that more mastication would be required for samples from older animals (due to the increased cross-linking of the collagen with increased age) and therefore more saliva would be released to increase the perceived sustained juiciness. This corresponds with the conclusions of Huff and Parrish (1993) that samples from carcasses of older animals (C to E maturity) were juicier ($p \leq 0,05$) than samples from carcasses of young bulls and steers (A maturity). Juiciness in their study was described as an estimation of the amount of free fluids released by chewing and it is therefore comparable to sustained juiciness in this study.

Discrimination between cuts/muscles

The first two canonical variates (CV1 and CV2) accounted for 80,9% of the total variation in the data, with latent roots 11,7 and 3,0 (should be >1). The canonical variate means for flavour, initial and sustained juiciness, thawing, evaporation and total cooking loss were negative, and positive for aroma and drip loss, and therefore CV1 clearly contrasts between these. The main discriminant variates of these characteristics for the different cuts/muscles are evaporation loss ($r = -0,978$), drip loss ($r = 0,710$), initial impression of juiciness ($r = -0,644$), and to a lesser extent juiciness ($r = - 0,523$) as these correlated the strongest with the CV1 scores (horisontal separation in Figure 5.3). The total cooking loss ($r = -0,797$) mainly discriminated between groups in the CV2 for the different cuts (vertical separation in Figure 5.3).

Closer inspection of the graphical presentation of the results shows that as expected, the cuts cooked by a dry heat cooking method (fillet (PM), rump (GM), ST, prime rib (LTP), wing rib (LTW), topside (SM) and loin (LL)) are contrasted against the cuts cooked by a moist heat cooking method. The shins (ECR & FDM), chuck (SV) and to a lesser extent the GB and brisket (PP) showing the greatest contrast. The cuts cooked by a dry heat cooking method showed less drip loss and more evaporation loss, and gave a more pronounced impression of initial and sustained juiciness than the cuts cooked by a moist heat cooking method.

The difference in cooking losses is due to more moisture being lost when the cuts are surrounded by dry air (dry heat cooking method). The evaporation loss increases, and the loss of moisture when cooking by moist heat is captured, resulting in higher drip loss (moist heat cooking method) (McCrae & Paul, 1974). The difference in juiciness between the two cooking methods is contrary to the findings of Ferger *et al.* (1972) who stated that there is little difference between dry and moist heat cooking methods in terms of cooking time, percentage total cooking loss, flavour, juiciness and tenderness.

TABLE 5.4
Least Square Mean Values (± Standard Errors) of Initial and Sustained Juiciness for Muscles Obtained From Three Age Groups (Average Chemical Fat of the Carcass used as Covariant = 15,74 %)

Muscle[1]	Model		Covariant [2]		Age						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
Initial Impression of Juiciness (8 = extremely juicy, 1 = extremely dry): Cooked (Dry Heat)											
LTP	2	0,0057	0,0023		0,3016	5,75	0,082	5,82	0,084	5,64	0,080
LL	2	0,0111	0,0180		0,0416	$5,70^{a}$	0,079	$5,44^{b}$	0,083	$5,69^{a}$	0,079
LTW	2	0,0166	0,0108		0,1946	5,68	0,090	5,59	0,095	5,45	0,090
ST	5	0,0001	0,0001		0,5121	5,74	0,075	5,76	0,079	5,86	0,075
GM	6	0,0001	0,0001	0,0001	0,3649	5,85	0,084	5,67	0,089	5,75	0,084
SM	0,8	0,1804	0,0678		0,5312	5,61	0,071	5,63	0,076	5,52	0,073
PM	2	0,0239	0,0256		0,0880	6,10	0,074	6,33	0,078	6,22	0,074
Cooked (Moist Heat)											
GB	2	0,0214	0,0193	0,0524	0,8089	5,62	0,072	5,68	0,075	5,68	0,071
VL	3	0,0011	0,0276	0,0234	0,0012	$5,55^{a}$	0,068	$5,72^{a}$	0,071	$5,36^{b}$	0,067
SV	2	0,0301	0,0385	0,0174	0,2840	5,70	0,079	5,88	0,083	5,76	0,079
PP	4	0,0001	0,0627		0,0003	$4,60^{a}$	0,083	$4,71^{a}$	0,087	$4,23^{b}$	0,085
BC	3	0,0004	0,0106	0,0082	0,0017	$5,38^{a}$	0,089	$5,29^{a}$	0,097	$4,95^{b}$	0,089
TBCL	2	0,0528	0,1012	0,0616	0,1051	5,46	0,084	5,70	0,089	5,48	0,084
OAE	1	0,0686	0,0450		0,2072	5,46	0,073	5,63	0,077	5,61	0,073
ECR&FDM	2	0,0058	0,0056		0,0669	$3,99^{a}$	0,096	$3,66^{b}$	0,101	$3,83^{ab}$	0,096
Sustained Juiciness (8 = extremely juicy, 1 = extremely dry): Cooked (Dry Heat)											
LTP	4	0,0001	0,0001		0,0587	5,18	0,080	5,43	0,082	5,40	0,078
LL	1	0,0440	0,0377		0,1070	5,05	0,083	4,95	0,088	5,21	0,084
LTW	2	0,0048	0,0044	0,0134	0,4203	5,35	0,095	5,39	0,100	5,22	0,095
ST	7	0,0001	0,0001		0,0337	$5,12^{a}$	0,076	$5,14^{a}$	0,080	$5,38^{b}$	0,076
GM	6	0,0001	0,0001	0,0001	0,8823	5,33	0,086	5,31	0,090	5,37	0,086
SM	0,04	0,8899			0,8899	5,11	0,068	5,16	0,075	5,16	0,071
PM	4	0,0001	0,0006		0,0036	$5,84^{a}$	0,070	$6,15^{b}$	0,074	$6,11^{b}$	0,071
Cooked (Moist Heat)											
GB	1	0,0509			0,0509	$5,11^{a}$	0,072	$5,26^{ab}$	0,077	$5,35^{b}$	0,074
VL	2	0,0148	0,1870	0,1366	0,084	$4,97^{a}$	0,078	$5,28^{b}$	0,082	$4,98^{a}$	0,078
SV	2	0,0223	0,0791	0,0627	0,0141	$5,37^{a}$	0,076	$5,68^{b}$	0,080	$5,46^{a}$	0,076
PP	4	0,0001	0,2423	0,1266	0,0002	$4,13^{a}$	0,081	$4,19^{a}$	0,086	$3,74^{b}$	0,083
BC	2	0,0029			0,0029	$4,98^{a}$	0,091	$4,96^{a}$	0,100	$4,58^{b}$	0,093
TBCL	1	0,0401			0,0401	$5,04^{ab}$	0,086	$5,22^{b}$	0,093	$4,89^{a}$	0,088
OAE	2	0,0005			0,0005	$4,95^{a}$	0,072	$5,35^{b}$	0,077	$5,21^{b}$	0,073
ECR&FDM	2	0,0018	0,0021		0,0448	$4,10^{a}$	0,095	$3,75^{b}$	0,101	$3,94^{ab}$	0,096

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] p-values of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

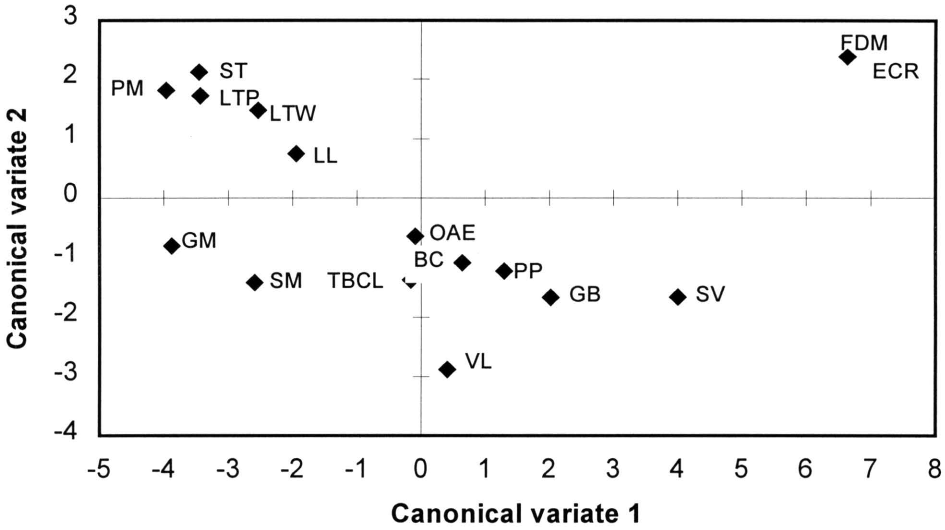

Fig 5.3: Plot of CV mean scores of various cuts[1]

In studying the CV2 results, the shins, ST, fillet, prime rib, wing rib and loin were contrasted against the thick flank, chuck and GB, and the former showed less total cooking loss. On the other hand the cuts that were cooked by a dry heat cooking method, namely ST, fillet, prime rib, wing rib and loin were contrasted against topside and rump, and the former showed the least amount of total cooking loss. Shins cooked according to a moist heat cooking method showed the least amount of total cooking loss, and the thick flank, chuck and GB the most. Spanier and Miller (1996) also described the differences between cuts. They found that different primal cuts react uniquely to heating because of the distinct fibre types, relative fat deposition and intercellular components.

The CVA mean scores for thawing and cooking losses of the various cuts in the three age groups combined are ranked in Table 5.5. No ANOVA or similar analysis was performed because the muscles had not been treated similarly. The GB, ST and fillet recorded the highest thawing losses, and the loin, topside and neck cuts the least. As expected, the cuts cooked according to a dry heat cooking method showed the highest percentage

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[1] LTP – *M. longissimus thoracis*; LL – *M. longissimus lumborum*; LTW – *M. longissimus thoracis*; ST – *M. semitendinosus*; GM – *M. gluteus medius*; SM – *M. semimembranosus*; PM – *M. psoas major*; GB – *M. gluteobiceps*; VL – *M. vastus lateralis*; SV – *M. serratus ventralis*; PP – *M. pectoralis profundus*; BC – *M. biventer cervicis*; TBCL – *M. triceps brachii caput longum*; OAE – *M. obliquus abdominis externus*; ECR – *M. extensor carpi radialis* and FDM – *M. flexor digitorum medialis*

evaporation loss compared to the cuts cooked by a moist heat cooking method, which showed the highest percentage drip loss.

The rump cuts showed the highest percentage total cooking loss at 39,1%, and the shins the lowest at 21,5%. Differences in cooking losses among cuts are also reported by Browning *et al.* (1990). The differences between cuts can be attributed to shape and size variations, the composition of the cuts, the spatial distribution of areas of lean meat, fat, connective tissue and bones, the characteristics of the meat surface, and any changes induced in the meat by heat, including protein denaturation, loss of water and the melting of fat (Seideman & Durland, 1984).

The CVA mean scores for the sensory analysis characteristics of the various cuts in the three age groups are presented in Table 5.6. The panel described the PM as the muscle with the most intense aroma and flavour, as well as the juiciest (both initial and sustained). Taking into consideration that cuts were not compared within tasting sessions, this result is contrary to popular belief (as noted by Lawrie, 1979) that the PM is the most tender cut in the carcass but lacking in flavour. The ECR and FDM were the driest cuts and had the blandest flavour compared to all the other cuts. Mc Keith *et al.* (1985) ranked the PM as having the most and the PP the least desirable flavour, but one should consider the fact that higher flavour desirability as measured in their study may not necessarily indicate higher flavour intensity as measured in this study. Yet, Carmack *et al.* (1995) ranked the GB the highest in beef flavour intensity, with the PM second and not statistically different from the GB.

Although the flavour intensity of the PM in their study coincided with the results of this study, the GB in this study had much lower flavour intensity. This could be because it had been cooked by a moist heat cooking method. Scheeder and Langholz (1996) also reported a low ranking for flavour intensity in the GB, similar to the results of this study. The variability in flavour between different muscles can partly be explained by differences in their amino acid and dipeptides content (Quali, 1991). In their study Carmack *et al.* (1995) ranked the SV and PM as the juiciest cuts, and this result corresponds with the findings of this study. In general the cuts cooked according to a moist heat cooking method ranked lower in initial and sustained juiciness, with the exception of the SV and the GB. Brady and Penfield (1982) also found that samples heated by a moist heat cooking method were judged to be drier ($p \leq 0,01$) than samples cooked in the oven.

TABLE 5.5
Ranking of Cuts According to % Thawing and Cooking Losses

Score	Thawing Loss	Evaporation Loss	Drip Loss	Total Cooking Loss
1	GB[1] (5,04)	Rump (28,43)	Chuck (31,45)	Rump (39,11)
2	ST[2] (4,44)	Topside (21,95)	Thick flank (28,67)	Thick flank (38,84)
3	Fillet (3,60)	Fillet (21,48)	GB (24,86)	Topside (36,84)
4	Shoulder (3,37)	Prime rib (20,16)	Brisket (22,92)	Chuck (34,09)
5	Rump (2,36)	ST (19,52)	Neck (20,97)	Brisket (31,93)
6	Shins (1,12)	Wing rib (17,12)	Shins (20,18)	GB (30,52)
7	Thick flank (1,05)	Loin (15,52)	Shoulder (19,04)	Shoulder (30,08)
8	Chuck (1,03)	Shoulder (11,04)	Thin flank (16,89)	Neck (30,08)
9	Prime rib (0,74)	Thick flank (10,17)	Topside (14,89)	Fillet (27,10)
10	Brisket (0,72)	Thin flank (9,90)	Rump (10,69)	Thin flank (26,83)
11	Thin flank (0,71)	Neck (9,11)	Loin (9,36)	Prime rib (26,37)
12	Wing rib (0,65)	Brisket (9,01)	Wing rib (8,11)	Wing rib (25,23)
13	Neck (0,45)	GB (5,66)	Prime rib (6,21)	Loin (24,81)
14	Topside (0,38)	Chuck (2,64)	Fillet (5,62)	ST (24,41)
15	Loin (0,24)	Shins (1,27)	ST (4,94)	Shins (21,46)

[1] Silverside: ST - *M. semitendinosus*;
[2] Silverside: GB - *M. gluteobiceps*

Effect of age by cut

The first two canonical variates (CV1 and CV2) accounted for 79,8% of the total variation in the data, with latent roots 12,4 and 3,4. The canonical variate means for drip loss were negative, and positive for all the other attributes. The discriminant attributes for the different cuts/muscles were evaporation loss (r = 0,977), drip loss (r = -0,710), initial juiciness (r = 0,647), and sustained juiciness (r = 0,525) that were similar to the findings on cuts alone. Similarly, total cooking loss (r = 0,821) was the main discriminant in CV2. The CV mean scores are presented in Figure 5.4. The fact that all three age groups are neatly grouped together for each cut/muscle indicates that the differences between cuts are much more discriminating than for age (indicated by the latent root < 1).

TABLE 5.6
Rating of Muscles [1] According to Sensory Evaluation Scores

Scores	Aroma [2]	Flavour [2]	Initial [3] Juiciness	Sustained [3] Juiciness
1	PM (6,27)	PM (6,24)	PM (6,22)	PM (6,03)
2	SM (6,09)	BC (5,88)	SV (5,78)	SV (5,50)
3	VL (6,08)	OAE (5,84)	ST (5,78)	LTW (5,33)
4	GB (6,07)	TBCL (5,72)	LTP (5,72)	LTP (5,32)
5	GM (5,96)	ST (5,66)	GM (5,72)	GM (5,30)
6	ST (5,93)	LTW (5,66)	GB (5,65)	GB (5,24)
7	SV (5,93)	GM (5,60)	LL (5,61)	ST (5,20)
8	ECR&FDM (5,91)	VL (5,60)	SM (5,58)	OAE (5,16)
9	BC (5,81)	SV (5,57)	LTW (5,58)	SM (5,14)
10	LTW (5,78)	GB (5,55)	OAC (5,56)	VL (5,09)
11	TBCL (5,78)	SM (5,50)	VL (5,55)	LL (5,07)
12	LL (5,68)	LTP (5,44)	TBCL (5,54)	TBCL (5,04)
13	OAE (5,62)	LL (5,43)	BC (5,21)	BC (4,83)
14	PP (5,59)	PP (5,22)	PP (4,52)	PP (4,03)
15	LTP (5,53)	ECR&FDM (5,04)	ECR&FDM (3,83)	ECR&FDM (3,94)

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; ST - *M. semitendinosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] 8 = Extremely intense, 1 = Extremely bland

[3] 8 = Extremely juicy, 1 = Extremely dry

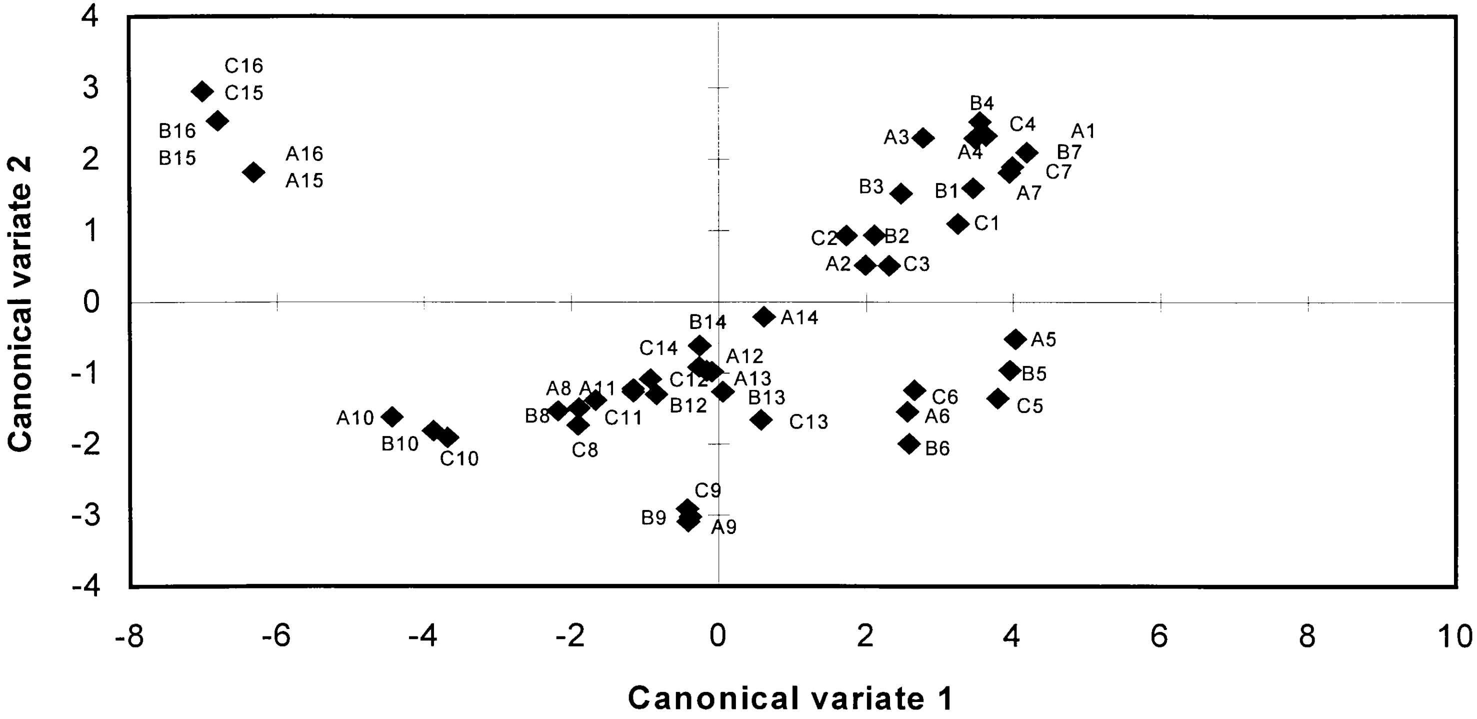

Fig. 5.4: Plot of CV mean scores of age groups[1] by cuts[2]

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C-age group ≥ 8 permanent incisors

[2] 1 – *M. longissimus thoracis (LTP)*; 2 – *M. longissimus lumborum (LL)*; 3 – *M. longissimus thoracis (LTW)*; 4 – *M. semitendinosus (ST)*; 5 – *M. gluteus medius (GM)*; 6 – *M. semimembranosus (SM)*; 7 – *M. psoas major (PM)*; 8 – *M. gluteobiceps (GB)*; 9 – *M. vastus lateralis (VL)*; 10 – *M. serratus ventralis (SV)*; 11 – *M. pectoralis profundus (PP)*; 12 – *M. biventer cervicis (BC)*; 13 – *M. triceps brachii caput longum (TBCL)*; 14 – *M. obliquus abdominis externus (OAE)*; 15 – *M. extensor carpi radialis (ECR)* and 16 – *M. flexor digitorum medialis (FDM)*

Correlation of age with juiciness, aroma and flavour

In the previous section it was shown that the aroma, flavour and juiciness of beef carcass muscles were closely and significantly ($p \leq 0{,}05$) related to animal age. A correlation matrix was constructed to determine whether these relationships were linear and this is summarised in Table 5.7. With one or two exceptions per attribute, the characteristics evaluated by the taste panel for the various muscles showed low linear correlation with the age of the animal.

TABLE 5.7
Correlation Coefficient (r) of Aroma, Flavour and Juiciness Related Characteristics of Muscle With Age as Independent Variable

Muscle [1]	**Dependent Variables**			
	Aroma [2]	**Flavour** [2]	**Initial juiciness**[3]	**Sustained juiciness** [3]
LTP	-0,442**	-0,146	-0,174	0,045
LL	0,118	0,199	0,053	0,132
LTW	0,144	-0,003	-0,107	-0,070
ST	-0,121	-0,016	0,148	0,243
GM	-0,032	-0,051	-0,078	-0,020
SM	-0,143	-0,120	-0,040	0,180
PM	0,081	0,273*	0,070	0,184
GB	-0,102	-0,251	0,065	0,205
VL	-0,193	-0,393*	-0,228	-0,035
SV	-0,002	-0,247	0,109	0,145
PP	-0,108	-0,437*	-0,430*	-0,426*
BC	-0,504**	-0,200	-0,275	-0,265
TBCL	-0,037	-0,036	-0,537**	-0,521**
OAE	0,246*	0,060	0,214	0,343
ECR	-0,235	-0,219	-0,051	-0,090
FDM	-0,290	-0,295	-0,069	-0,142

[1] Note that thawing, evaporation, drip and total cooking loss analyses were performed on the cuts and aroma and initial juiciness were performed on the muscles; LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; ST - *M. semitendinosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] 8 = Extremely intense,1 = Extremely bland

[3] 8 = Extremely juicy,1 = Extremely dry

* = $p \leq 0{,}05$; ** = $p \leq 0{,}01$; *** = $p \leq 0{,}001$

Correlation between juiciness, aroma and flavour

A correlation matrix was constructed and is summarised in Table 5.8 with sustained juiciness as an independent variable. Initial juiciness showed a constant highly significant correlation ($p \leq 0{,}001$) of between $r = 0{,}723$ in the GB and $r = 0{,}943$ in the GM with sustained juiciness, implying mutual dependency (Cross *et al.*, 1973a). In this study aroma showed insignificant correlation with sustained juiciness, with the exception of the GB ($r = -0{,}624$ with $p \leq 0{,}001$) and the SV (with $r = 0{,}412$ and $p \leq 0{,}05$).

TABLE 5.8

Correlation Coefficient (r) of Thawing and Cooking Losses, Initial Juiciness and Aroma of Muscles/Cuts with Sustained Juiciness as Independent Variable

Muscle[1]	**Dependent Variables**					
	Thawing loss[2]	**Evaporation loss**[2]	**Drip loss**[2]	**Total cooking loss**[2]	**Aroma**[3]	**Initial Juiciness**[4]
LTP	-0,362*	-0,230	0,185	0,011	0,108	0,837***
LL	-0,202	-0,384*	-0,070	-0,445**	0,043	0,921***
LTW	-0,224	-0,569**	0,155	-0,104	0,036	0,805***
ST	-0,241	-0,128	0,292	0,009	-0,203	0,929***
GM	0,074	-0,506***	0,392**	-0,265	-0,149	0,943***
SM	-0,000	-0,005	-0,044	-0,063	-0,025	0,814***
PM	-0,076	-0,158	-0,287	-0,329*	0,013	0,917***
GB	-0,321*	0,061	-0,022	0,027	-0,624***	0,723***
VL	-0,266	-0,158	-0,232	-0,464**	-0,083	0,820***
SV	0,037	0,153	-0,091	-0,029	0,412*	0,825***
PP	0,034	0,075	-0,271	-0,239	-0,045	0,880***
BC	0,051	0,061	-0,467*	-0,512**	0,088	0,864***
TBCL	-0,222	-0,507**	0,066	-0,570**	0,111	0,900***
OAE	0,009	-0,270	0,099	-0,161	0,195	0,828***
ECR&FDM	-0,091	-0,096	-0,029	-0,050	0,154	0,892***

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; ST - *M. semitendinosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] Percentage (%)

[3] 8 = Extremely intense, 1 = Extremely bland

[4] 8 = Extremely juicy, 1 = Extremely dry

Only two significant ($p \leq 0,05$) correlation (Table 5.8) were found between thawing loss and sustained juiciness, namely LTP ($r = -0,362$) and GB ($r = -0,321$). For evaporation loss, the LTW ($r = -0,569$ with $p \leq 0,01$), the TBCL ($r = -0,507$ with $p \leq 0,01$), the GB ($r = -0,506$ with $p \leq 0,001$) and the LL ($r = -0,384$ with $p \leq 0,05$) correlated with sustained juiciness. For drip loss only the BC ($r = -0,467$ with $p \leq 0,05$) and the GM ($r = 0,392$ with $p \leq 0,01$) correlated with sustained juiciness. Regarding total cooking loss the TBCL ($r = -0,570$ with $p \leq 0,01$), the BC ($r = -0,512$ with $p \leq 0,01$), the VL ($r = -0,464$ with $p \leq 0,01$), the LL ($r = -0,445$ with $p \leq 0,01$) and the ($r = -0,329$ with $p \leq 0,05$) correlated with juiciness.

TABLE 5.9
Correlation Coefficient (r) of Aroma and Juiciness of Muscles with Flavour as Independent Variable

Muscle[1]	**Dependent Variables**		
	Aroma [2]	**Initial Juiciness** [3]	**Sustained juiciness** [3]
LTP	0,402**	0,317*	0,276
LL	0,284	0,053	0,105
LTW	-0,070	0,221	0,224
ST	0,103	0,419**	0,344*
GM	-0,022	0,651***	0,641***
SM	0,173	0,174	0,150
PM	-0,105	0,128	0,162
GB	-0,161	0,356*	0,211
VL	0,169	0,013	-0,049
SV	-0,189	-0,019	0,016
PP	0,264	0,492**	0,533**
BC	0,118	0,203	0,418*
TBCL	0,112	0,438*	0,519**
OAE	0,103	0,275	0,408*
ECR&FDM	0,218	0,532**	0,529**

[1] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; ST - *M. semitendinosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

[2] 8 = Extremely intense, 1 = Extremely bland

[3] 8 = Extremely juicy, 1 = Extremely dry

Although Bouton *et al.* (1975a) reported low correlation between cooking loss and juiciness, they explained it by means of temperature distribution that varies in samples prepared according to conventional methods. However, Bouton *et al.* (1975b) and Brady and Penfield (1982) reported highly significant ($p \leq 0{,}001$) correlation between cooking loss and juiciness. With the exception of the LTP ($r = 0{,}402$ with $p \leq 0{,}01$) aroma intensity showed a low linear correlation with flavour intensity (Table 5.9), suggesting independence of the two attributes. Initial juiciness and sustained juiciness correlated significantly ($p \leq 0{,}05$) with flavour in eight of the 16 muscles that were studied. According to Bouton *et al.* (1975a), flavour changes in cooked meat could well increase salivation and hence apparent juiciness, although these changes would be highly subjective and properbly impossible to assess objectively.

CONCLUSIONS AND RECOMMENDATIONS

Due to the design of the project, which included a similar fat range in each age group, and the fact that the percentage chemical fat of the carcass was used as a covariant to adjust for differences between initial fat, the results were very interesting. According to the CVA, flavour intensity is the main discriminant between the three age groups and it declines with age. This finding is probably due to changes in the amino acid, protein and nucleotide metabolism (Smulders *et al.*, 1991). Total cooking loss increased with increased age of the animal, suggesting increased denaturation of protein with age, or increased cross-linking of collagen with age, resulting in decreased water-holding capacity with increased moisture loss upon heating or cooking. There was no clear linear increase in aroma and flavour intensity as is generally believed. According to the CVA results, the aroma and flavour decreased with increased age. In general the initial impression of juiciness decreased with increased age and sustained juiciness increased (although not linearly) with age, irrespective of the muscle. The decrease in initial juiciness with increased animal age could be attributed to the inability of the muscle to retain water with increased age. This in turn results in higher cooking losses in cuts from older animals, with an associated drier end-product, without the rapid release of meat fluid during the first few chews as found in meat from young animals. The result that sustained juiciness increased with increased age in some muscles, may be explained by the fact that more mastication would be required for samples from older animals due to increased cross-linking of the collagen with increased age. Therefore more saliva is released, increasing the perceived sustained juiciness. This finding that initial juiciness decreased with increased animal age and that sustained juiciness generally increased with increased animal age should be further investigated, including the measurement of final pH and sarcomere lengths.

The cuts cooked by a dry heat cooking method were juicier (both initial and sustained) according to the CVA than those cooked by a moist heat cooking method. The PM was not only the juiciest muscle but also had the most intense aroma and flavour compared to all the other muscles. The ECR and FDM were the least juicy and had the least intense flavour, despite the fact that they were cooked using a moist heat cooking method.

In conclusion, and based on the CVA (Figure 5.3), it is recommended that when cuts are grouped together they exhibit similar traits, therefore only one of these cuts would be sufficient to describe the group's behaviour in terms of particular characteristics. It is proposed that it is not necessary to differentiate (based on the discriminant analyses) between the FDM and the ECR cooked as 5 cm thick beef retail cuts. Only the LTW or the LTP would be sufficient to describe cuts cooked as intact joints by a dry heat cooking method, and that either the GB or the BC would describe the group subjected to a moist heat cooking method in a similar manner. The SV, GM, VL and SM are not included in these groupings. This implies that the 16 cuts could be adequately described by seven cuts in terms of juiciness and flavour-related characteristics, which means a great saving in costs and time. These groups were more clearly defined by the CVA than by traditional statistical methods such as the PCA and, together with ANOVA analyses, more subtle differences could be explained. The usual correlation coefficients could not effectively describe the true groupings of similar or dissimilar cuts.

It is strongly recommended that animals of the B-age group with four and six teeth and of various fatness classes should be evaluated in a similar manner. Therefore, the influence of these maturity groups on the different parameters used for describing the juiciness and flavour of beef can be determined or quantified.

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6

Effect of Age and Cut on the Nutritional Content of South African Beef

ABSTRACT

Lean meat provides significant amounts of the dietary nutrients required in a healthy diet. The protein is of a high quality, quantity and many essential vitamins and minerals (such as iron) are present in sufficient quantities. Iron deficiency is the world's most common nutritional ailment. The diversity of the South African population requires that valid local nutrient composition data are available. A composite sample of boneless meat of each group of three similar cuts from carcasses of three different age groups (as defined in the current South African classification system) and representing the full variation in fatness within each age group, was obtained on the commercial market and analysed on a double blind basis by various laboratories. The physical composition (proportion of subcutaneous fat, meat and bone) of each right side cut was assessed and then analysed for nutrient content, while each left side cut was cooked prior to nutrient analyses. All cuts (subcutaneous fat plus meat; n = 270 for raw and n = 270 for cooked cuts) were analysed for moisture, protein, fat, amino acids (including tryptophan and cystine), fatty acid profile (14:0, 16:0, 16:1, 18:0, 18:1, 18:2 and 20:4), cholesterol, water-soluble vitamins (thiamin, riboflavin, nicotinamide, pyridoxine, folic acid, cyanocobalamin, biotin and calcium pantothenate) and, minerals (phosphorus, calcium, magnesium, potassium, sodium, copper, zinc, manganese and iron).

The physical composition (proportions of meat, fat and bone) of the carcass and the various cuts had the most discriminating effect on the difference between the three age groups (carcass meat content). However, when the data was analysed without the physical composition of the carcasses and cuts, lysine and iron were higher and

linoleic acid lower in the C-age group animals than in A- or B-age animals for both raw and cooked cuts. Without the physical composition of the carcasses and cuts the attributes that mostly discriminated between the different cuts within the same carcass were hydroxyproline, glycine and some minerals (phosphorus, potassium and magnesium). Differences in fat content (subcutaneous and proximate), meat, moisture, various fatty acids (palmitic, stearic and oleic acids) and calcium were also found between the different cuts.

As iron-deficiency anaemia is the most widespread nutritional disease in the world today, it is reassuring to know that the meat mostly consumed by the people with severe iron-deficiency anaemia in the rural areas of South Africa, are adequate to meet this need. Lysine as one of the nine essential amino acids for adults, and higher in C-age group, can contrary to common belief (that it is of inferior quality), be recommended to form part of a balanced diet. This finding is highly significant as people that mostly suffer from iron-deficiency anaemia and essential amino acid deficiency are more likely to be able to afford meat from older animals due to the inverse relationship of price with age of the animal in South Africa.

For the prediction of carcass composition from a single cut, the neck and chuck emerged as the cuts that were the closest in composition to that of the carcass. This was when the physically dissected tissues of subcutaneous fat, meat and bone of both the carcass and cuts respectively, were included for raw cuts. However, when the physically dissected tissues of subcutaneous fat, meat and bone were excluded, the shoulder was the closest in the nutrient composition to the raw carcass. In the cooked cuts the prime rib was the closest with the shoulder second to describe the nutrient composition of the carcass. These results should form the basis for future nutrient analysis or monitoring of existing data.

INTRODUCTION

The absolute and relative per capita consumption of red meat in South Africa and abroad is consistently declining in favour of white meat as well as other non-meat proteins. The annual per capita consumption of red meat in South Africa declined from 39,3 kg in 1961 to 26,2 kg in 1993 to 18,7 kg in 1996, compared to poultry meat that increased over the same period from 2,4 kg to 18,8 kg to 19,0 kg (Abstract of Agricultural Statistics, 1996). Although the price difference between white and red meat is recognised as contributing to this phenomenon, another important reason is the health risk associated with the consumption of products high in total and saturated fat, as in some animal products. In order to comply with the South African consumers' preferences for fatness the fat level of the target grade (Super A) beef carcasses has changed considerably from 32% in 1949 to 18% in 1981 to 13% in 1991 (Naudé, 1994).

Diets of individuals are usually analysed by utilising information contained in food composition tables. South African tables however contain information mainly generated in other countries. As recently as in 1991 only 18% original South African values were contained in the Medical Research Council Food Composition Tables (Langenhoven, 1994). These Food Composition Tables must not only be comprehensive and representative of available foods but are an essential tool in nutritional research, for planning and assessing nutrition intervention studies, planning national food and nutrition policies and prescribing therapeutic and institutional diets. The validity of nutritional epidemiological studies depends on accurate food consumption and food composition data (Greenfield & Southgate, 1992).

Meat is a primary dietary component and forms an important part of a balanced and varied diet (Kauffman & Breidenstein, 1983). The nutritional attributes of meat, which provide a major proportion of consumer requirements for protein, some vitamins and certain minerals, are highlighted work on the nutritional value of meat in other countries (Breidenstein, 1987; Johnson, 1987). The nutrient profiles of meat have been updated in Australia (Johnson, 1987), United Kingdom (Chan *et al.*, 1995) and more recently in the United States of America (USDA, 1997). This ensures consistency with changes in carcass characteristics, retail and food preparation practices and provides additional information. In the United Kingdom earlier tables were based on the composition of meat in the early 1970s. Their new tables include a wide range of cuts of beef, both raw and cooked in a variety of ways. It also reflects the substantial changes over time in the composition of carcass meat, especially reduction in the amount of fat both on the carcass itself and after trimming in the shop or at home, as well as the changes in cooking methods (Chan *et al.*, 1995). In the United States the meat tables have been extensively revised since the late 1970s. The results of their first study on beef retail cuts trimmed to 1,3 cm (half an inch) subcutaneous fat were published in 1986 (USDA, 1986). However, as soon as this was completed the retail segment of their beef industry has already identified a need for more nutrient information for beef retail cuts trimmed to 0,6 cm (a quarter inch). As soon as meat containing a 0,6 cm fat trim was analysed, consumers (based on the recommendations of health professionals) were already demanding meat with no visible subcutaneous fat, trimmed to 0,0 cm external fat (Jones *et al.*, 1992). With the publication of the first Australian values for beef, very real differences were found between their previous values obtained from other countries and their present values (Cashel & Greenfield, 1995).

Data from other countries cannot readily be applied to the South African situation for various reasons. Primarily, Choice beef carcasses in the USA contain on average between 30% and 35% fat (Topel, 1986) versus the local 18% of target grade carcasses. In the USA, meat is trimmed according to consumers' requirements. Visible intramuscular fat or marbling is regarded as essential in the USA and it varies from 1,8% to 10,4% as mean values for the marbling scores (Savell *et al.*, 1986), whereas 1% to 2% marbling is found in South African meat (Klingbiel, 1984). Such a high percentage of intramuscular fat cannot be attained to the exclusion of excessive quantities of subcutaneous and intermuscular fat. The American public has, however, been conditioned to desire it, thus requiring that excess fat be cut away or trimmed. In addition, the very real differences in the definition of joints and in dissection methods in the various countries, make the direct application and interpretation of the American and Australian nutrient data on meat in the South African context, almost impossible (Meat Science Section, 1981).

Due to these discrepancies between the local and foreign products a need was identified for valid South African data to be used in the analyses and recommendations of diets and nutrient intakes of all South Africans. The relationship of nutrient content to animal age as per dentition has not yet been investigated, even though age is one of the two variables (the other being carcass fat cover) included in the South African beef carcass classification system. Therefore, the compilation of sound scientific information regarding the nutritive value of red meat in South Africa has been identified as a matter of great urgency. Results from this research will be used in the compilation of nutrient tables for South African meat. The objective of the study was to research the effect of age on the nutrient content of raw and cooked beef cuts of carcasses found in the South African carcass classification system. A second objective was to determine which cut/s replicated the carcass the closest regarding nutrient content.

MATERIALS AND METHODS

Source of materials

The beef carcasses (*n* = 54) used in this study had a mass range of 190 kg to 240 kg. No specific genotype was chosen, because carcasses had to be representative of the market and that the South African classification system is based on age and carcass fatness regardless of genotype. Variation in fatness due to breed (carcass maturity differences) is therefore accounted for. Only steers and heifers were included in this sample due to the small proportion of bull carcasses currently available on the South African market. Please refer to Table 6.1 for a schematic diagram of the research design.

TABLE 6.1
Experimental Design for Determination of Nutrient Content of Beef Carcasses

Age group			**Total number of carcasses**
A	B	C	
18	18	18	54

The three age groups were the 0 (no permanent incisors) or < 793,0 ± 6,4 days, the 2 (permanent incisors) or between > 793,0 ± 6,4 days and < 1 001,0 ± 8,6 days, and the 8 tooth > 1 462,0 ± 10,5 days (Steenkamp, 1970). Due to the fact that carcass fatness influences lean yield, carcasses representing the full fatness spectrum (of all 6 fat classes) within each age group were selected. Firstly, to ensure that visually assessed carcasses were representatively selected for the various fatness levels, it was decided to in the first instance determine the percentage chemical fat in each prime rib cut. Secondly, fat thickness of each carcass (between the 10th and 11th thoracic vertebrae, 5 cm from the midline of the carcass) was measured. Thirdly, the subcutaneous fat content of both the prime rib cut and the total carcass was determined. These values were then checked against the norm for each fatness level and thus resulted in the correct classification within each fatness level of the 54 carcasses.

These carcasses were obtained on the commercial market (at the largest abattoir in the country) by qualified classifiers. The carcasses were electrically stimulated (500 V) within 10 minutes of stunning, dressed, halved, chilled overnight at between 0°C and 5°C labelled and transported to the ARC-ANPI in a refrigerated truck.

Sampling for nutrient content

Each of the right sides of beef was subdivided into 15 wholesale cuts (including the fillet) according to Figure 6.1. Each cut was then accurately weighed and dissected (at 10°C ambient temperature) into subcutaneous fat, meat (muscle and inter- and intramuscular fat) and bone, in order to determine the physical composition of each cut and, by summation, the entire carcass.

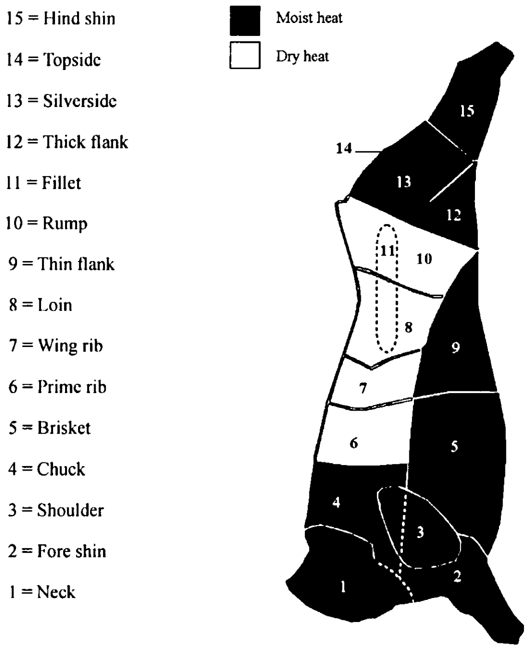

Fig. 6.1: Wholesale cuts from the carcass

A composite sample of each group of three similar cuts from the three carcasses was used in the analysis (3 age groups *x* 6 fatness levels *x* 15 cuts = 270 samples raw (left sides) and 270 samples cooked (right sides)). The use of composite samples for analysis rather than individual samples was justified due to budget constraints and it is an accepted approach in food composition studies (Greenfield & Southgate, 1992). The cuts (meat plus subcutaneous fat) were analysed without trimming the subcutaneous fat or removal of sinews normally associated with each cut.

The subcutaneous fat plus meat obtained from each of the identical cuts of the three right sides of each age and fatness group was cubed, thoroughly mixed and then minced first through a 5 mm and then through a 2 mm mesh plate. Each composite sample was then divided into the amounts required for the various analyses. The samples were stored at -40°C after coding and packaging and distributed to the laboratories responsible for the determinations of the raw meat at regular intervals.

Each of the left sides of beef was subdivided into 15 primal cuts (including the fillet) according to Figure 6.1. Each cut was labelled, deboned if applicable, vacuum-packaged, aged at 4°C for 10 days post-mortem, stored at -40°C before being cooked according to an appropriate cooking method. Cuts were defrosted at 6°C to 8°C for periods varying between 24 to 36 hours (depending on mass) until an internal temperature of 2°C to 5°C was reached (American Meat Science Association (AMSA), 1978). The prime rib, wing rib, loin, rump, topside and fillet cuts were cooked according to a dry heat cooking method, while the silverside, thick flank, chuck, brisket, neck, shoulder, thin flank, hind and fore shins cuts were cooked according to a moist heat cooking method. All cuts were cooked in primal form, excluding the loin cuts which were oven-broiled under direct radiant heat as 25 mm thickness steaks and the shins that were broiled as 50 mm retail cuts. Distilled water (100 ml) at room temperature was added to each moist heat dish before cooking commenced. Each cut was cooked individually to an internal temperature of 70°C. A J-type thermocouple placed in the geometric centre of each cut to be evaluated, linked up to a centrally controlled computer system, was used to record internal temperature. A hand-model Kane-Mane probe equipped with a T-type thermocouple was used to check the final temperature (70°C) of the cut prior to removal from the oven.

The cooked meat obtained from each cut was chilled (4°C) overnight, deboned if applicable, cubed, thoroughly mixed with the three identical cuts of each age and fatness group and then minced first through a 5 mm and then through a 2 mm mesh plate. Each composite sample was then separated into the amount required for each analysis. The samples were stored at -40°C after coding and packaging and distributed to the different laboratories for analysis of the cooked meat at regular intervals.

All the cuts were analysed on a double blind basis over a period of three years. The laboratories responsible for the determinations were selected on a contract basis. Unless otherwise stipulated, the ARC-ANPI laboratories performed all analyses.

Nutritional analysis

Proximate chemical analysis

The proximate analyses of the cuts were carried out to determine the percentages of total moisture (oven-dry method), fat (Soxhlet extraction with diethyl ether for 16 hours), nitrogen (Kjeldahl-method using a Büchi 430 block digester and a Büchi 322 distilatlion unit) (N *x* 6,25 = protein) and ash (by ignition at 800°C) in the tissue of each cut were done according to AOAC methods (1995). Moisture and fat content of samples were determined in triplicate and protein content was determined in duplicate. If the sum of the proximate values did not meet 100±1,5% samples were reanalysed.

Amino acid profile

Amino acid determination was carried out by high-performance liquid chromatography (HPLC), following the method of Einarsson *et al.* (1983). Amino acid determination was performed during three separate hydrolyses, namely:

Hydrolysis 1: 17 amino acids comprising arginine, hydroxyproline, serine, aspartic acid, glutamic acid, threonine, glycine, alanine, tyrosine, proline, methionine, valine, phenylalanine, isoleucine, leucine, histidine and lysine were determined. An amount of ground, freeze-dried meat was weighed accurately and hydrolysed with 6 N hydrochloric acid. Internal standard (∝-amino and ß-guandino propionic acid) was added to the hydrolysate, after which the hydrolysate was filtered. An aliquot of the hydrolysate was dried under nitrogen-flow. The hydrolysate was derivated with FMOC reagent (9-fluorenylmethyl chlorofomate), after which the amino acid content was determined by means of an HPLC (using an AminoTag column) and, as the eluent, a tertiary gradient of pH, methanol and acetonitrile. Peak detection was carried out by means of a fluorescent detector.

Hydrolysis 2: Cystine determination. The procedure followed was identical to the above except that, prior to hydrolysis, cysteine was oxidised to cystine by the addition of a peroxide-formic acid blend. The addition and subsequent evaporation of hydrobromic acid reduced excess oxidising agent.

Hydrolysis 3: For tryptophan determination, an amount of ground, freeze-dried meat was hydrolysed enzymatically using protease. After filtration through a 0,45 µm filter, tryptophan was determined by means of HPLC, using an AminoTag column and, as the eluent, a blend of buffer methanol and acetonitrile. Peak detection was carried out by means of a fluorescence detector.

The amount of amino acid was expressed on a wet mass basis following each analysis.

Fatty acid profile

The Nutritional Intervention Programme (NRPNI) of the Medical Research Council (MRC) was contracted to determine the fatty acid profiles of all samples. Weighed, duplicate samples were homogenised with a Polytron homogeniser in a chloroform-methanol (2:1) mixture, containing 0,01% Bulylatect-lydroxy-toluene as an anti-oxidant. Extracts were analysed by gas liquid chromatography.

Chloroform-methanol extracts were trans-methylated with methanol-sulphuric acid. Fatty acid methyl esters were extracted with n-hexane and analysed by gas liquid chromatography, as described by Benadé *et al.* (1988) and Smuts *et al.* (1992). Heptadecanoic acid (C17:0) was used as an internal standard. The fatty acids were determined qualitatively (per cent of total fatty acids) but were statistically analysed (mg/100 g sample) to be similar to all the other analyses. Due to the real difference in fat content between various countries it was essential to determine the ratio for this set of data. This was obtained by graphimetrically analysing three sets of samples and the development of a regression equation where $y = 4{,}97 + 0{,}47x$ ($r = 0{,}96$); with y = total fatty acids (mg/100 g) and x = % chemical fat for each cut. The result for y was then multiplied with the % fatty acids as determined. In the present study the mean for the ratio of fatty acids to fat was 0,83. This compared favourably with the 0,85 ratio determined by Slover *et al.* (1987), but differed substantially from the 0,916 for lean beef as proposed by Anderson *et al.* (1975) and used by the USDA. The following fatty acids were determined: 14:0 (myristic), 16:0 (palmitic), 16:1 (palmitoleic), 18:0 (stearic), 18:1 (oleic), 18:2 (linoleic) and 20:4 (arachidonic).

Total cholesterol

The cholesterol content of all the samples was determined by the NRPNI of the MRC. Weighed, duplicate samples were homogenised with a Polytron homogeniser in a chloroform-methanol (2:1) mixture, containing 0,01% Bulylatect-Lydroxy-toluene as an anti-oxidant. Extracts were analysed by gas liquid chromatography. Total cholesterol in chloroform-methanol extracts was determined by gas liquid chromatography, using stigmasterol as an internal standard (Smuts *et al.*, 1992).

Water-soluble vitamins

The levels of water-soluble vitamins in all samples were determined (using a microbiological method) by the South African Bureau of Standards (SABS). Due to the extremely low levels of ascorbic acid in fresh red meat, it was decided not to determine the levels of this vitamin.

Thiamin, riboflavin, nicotinamide, pyridoxine, biotin and folic acid were determined according to Barton-Wright (1961). Cyanocobalamin (Vitamin B_{12}) levels were determined according to the accepted AOAC method (1995). Calcium pantothenate levels were determined according to the United States Pharmacopoeia XXII (1990).

Minerals

The Institute of Soil, Climate and Water (ARC-ISCW) was contracted to determine the mineral content of all samples. Potassium was determined according to a flame photometric method. Zinc and phosphorus were determined according to a spectrophotometric method. Copper, iron, manganese and zinc were determined using an atomic absorption spectrophotometric method. Calcium and magnesium were determined using an E.D.T.A Titration method. These determinations were carried out according to the accepted AOAC methods (1995).

Food energy content

The energy value of each cut was calculated from the percentages of protein and fat:

1 g of protein = 4,184 x 4,27 = 17,87 kJ

1 g of fat = 4,184 x 9,02 = 37,74 kJ.

STATISTICAL ANALYSIS

In order to establish which of the large set of correlated variates were the most important in discriminating between the age groups (A, B and C) and/or the 15 cuts, canonical variate analysis (CVA) (GENSTAT 5, 1996), also known as linear discriminant analysis, was used. Multivariate techniques, such as principal component analysis (PCA) are used to reduce a large set of variates into a smaller set that explains most of the variation in the entire data set. PCA (GENSTAT 5, 1996) was performed on all the different variates for each of the 15 cuts, but will not be presented due to limited space (n = 54 raw *x* 15 cuts and 47 cooked *x* 15 cuts = 1 515 plots). PCA identified that fatness of the carcass was one of the most important gradients or factors in this multivariate data space (data matrix) and for that reason was used as covariant in the ANOVA. PCA is suitable when one is interested in the groupings of individuals, and as definite groupings were observed in this data set, CVA was the preferred choice. The large number of variates was firstly reduced to a smaller set, which accounted for most of the variability in all the variates. If there was a strong grouping or trend in the data set, usually only a few of the important variates which influence the new variate, called canonical variates (CV), were obtained. A plot of the mean scores of each group is obtained. This plot is an easily understandable graphical representation of the similarities or groupings of the original age and/or cut groups. Furthermore, by correlating the scores with the original variates, the most important variates discriminating between the new groups were identified (Digby & Kempthorne, 1987).

In this study the variates were the physical dissection data of the carcass and cuts (raw), as well as all the nutrients that were measured in each cut (raw and cooked) and expressed as g per 100 g edible portion. The logarithms of the variates were used to stabilise variances. However, physical dissection results do not necessarily form a part of the statistical analyses of nutrient composition, but it could be useful for interpreting results. Therefore, the carcass data namely fat content, subcutaneous fat, meat and bone were excluded in the second CVA, with carcass and cut data excluded in the third CVA. As only the directions of the main variability in the data matrix are given attention to in these analyses, the more subtle sources of variation were investigated by ANOVA (SAS, 1996) as proposed by Næs *et al.* (1996). A correlation matrix was constructed to test for correlation between the different variables. To ensure that the effect of animal age was determined and not the effect of fatness of the carcass, the % chemical fat of the carcass was used as covariant (X), both as natural X and X^2 in a PROC GLM (SAS, 1996) procedure. The percentage fat was determined by proximate analyses for the 15 wholesale cuts and calculated for the carcass according to the relative mass of each cut. In searching for the most simplistic model the covariant was removed from the model if not significant (very generously at $p \geq 0,15$) starting with X^2 and continuing with X. The carcass mean scores of the different variables of the various cuts for the three age groups were subjected to an ANOVA analysis to test for differences. Separation of the mean scores for interaction of the different variables for the various cuts for the three age groups was achieved by the application of Tukey's method (SAS, 1996). However, as Tukey's method is more lenient than CVA only the differences identified by CVA as being > 0,5 were discussed.

The second objective of the study was achieved by using the carcass values to determine which cut/s replicated the carcass the closest regarding nutrient content. Nutrient content of the carcass was calculated based on the % contribution of each cut to the carcass. All the nutrient data for each cut were subjected to CVA analyses together with the carcass values to determine which cut/s grouped the closest to the carcass. This procedure was performed on different combinations of the data.

RESULTS AND DISCUSSION

Discrimination by age for raw meat

When all the characteristics were included in the CVA, the first canonical variate (CV1) accounted for 65,8% (Table 6.2) and the second canonical variate (CV2) accounted for 34,2% of the total variation in the data with large latent roots of 11,71 and 6,09 (should be >1 to be meaningful). The main variate that discriminated between the nutrient composition for the three age groups in CV1 (horisontal) were iron (r = 0,712), linoleic acid (C18:2) (r = -0,657) and folic acid (r = 0,649). These characteristics correlated the strongest with the CV1 scores. Thus CV1 contrasted A- and B-ages (negative scores) with C-age (positive score), i.e. they were more similar with respect to the discriminate variates mentioned. Lysine (r = -0,673) discriminated mainly between the three age groups in the CV2 (vertical axis) i.e. between A- and B-ages in all three of the CVA procedures. The CV mean scores are presented in Figure 6.2.

Biotin (r = 0,487), pyridoxine (r = 0,478), cholesterol (r = -0,433) and bone of the carcass (r = 0,416) were the characteristics that, in the first CVA procedure also made a contribution to the variation in the data, however their correlation coefficients were < 0,5. In the second CVA procedure (Figure 6.3) which excluded the carcass values iron, linoleic acid and folic acid correlated even stronger with CV1, as well as pyridoxine (r = -0,513). The results of the third CVA procedure which excluded the carcass values and cut dissections (Figure 6.4) were identical to that of the second CVA, with the exception of biotin (r = -0,500) that was added.

The results can be summarised as follows (according to the variates that discriminated the most in the CVA): iron, folic acid, pyridoxine and biotin were higher and linoleic acid was lower in the C-age group animals than in A- or B-age animals. Lysine was higher in animals of the B-age group compared to the A-age group, with those of the C-age group average. To test if these differences were significant for carcass values the results of Tukey's method of separation of the means are summarised in Table 6.3.

According to these results age of the animal had a significant effect on lysine, with B-age group (2 tooth) carcasses containing significantly ($p \leq 0,01$) more lysine than those from the A (0 tooth) and C (8 tooth) age groups. Linoleic acid decreased significantly ($p \leq 0,001$) with age. It was lower in carcasses of the C-age group compared to the B-age group that in turn was less than the A-age group. Biotin and folic acid were significantly ($p \leq 0,05$) lower in the A- (0 tooth) and B- (2 tooth) age groups compared to those from the C-age group (8 tooth). The differences for pyridoxine and iron between carcasses of the three age groups were not significant.

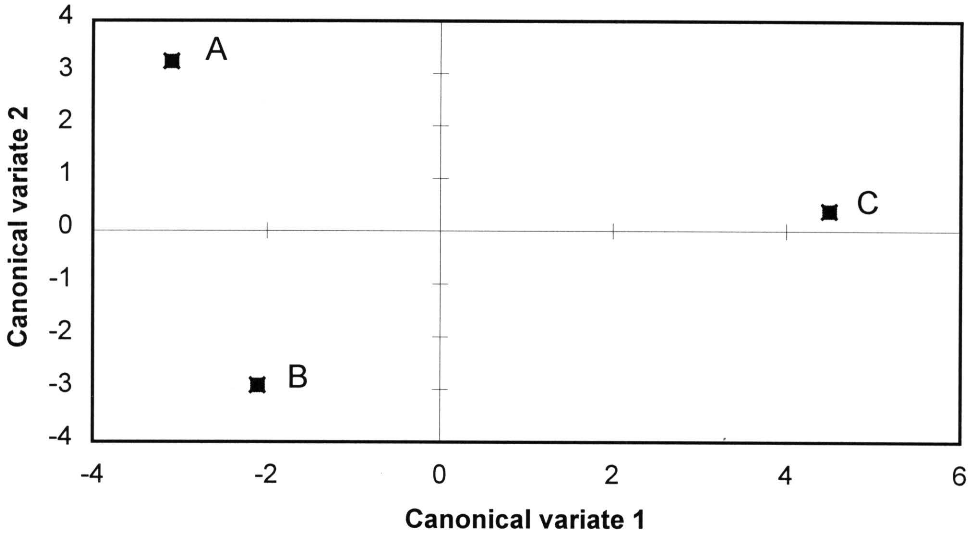

Fig. 6.2: Plot of CVA1 mean scores of three age groups[1]
(Raw)

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C age group ≥ 8 permanent incisors

Discrimination by age for cooked meat

In the CVA the first canonical variate (CV1) accounted for 58,4% (Table 6.4) and the second canonical variate (CV2) accounted for 41,7% of the variation in the data with latent roots of 6,84 and 4,88 (should be > 1 to be meaningful). Linoleic acid (r = -0,741) and iron (r = 0,514) correlated the strongest with CV1 (Figure 6.5). Thus CV1 contrasted A-age (negative score) with B- and C-age (positive score), i.e. they were more similar with respect to the discriminating variates. Alanine (r = 0,429), valine (r = 0,459), leucine (r = 0,460), lysine (r = 0,410), thiamin (r = -0,439) and sodium (r = 0,424) were the characteristics that also made a contribution to the variation in the data, however their correlation coefficients were < 0,5. No clear contrast was found for CV2 (vertical axis).

These differences were tested for significance using Tukey's method of separation of the means (Table 6.3). Tukey's method is more lenient than CVA and therefore only the CVA differences that were greater than 0,4 will be discussed. According to these results for cooked meat of A (0 tooth) age group carcasses contained significantly ($p \leq 0,01$) more linoleic acid and sodium with less iron and lysine than those from the B (2 tooth) and C (8 tooth) age groups.

TABLE 6.2

Canonical Variate Percentage Variation of the First Two Canonical Variates of the Three Age Groups and the Correlation Coefficients of the Nutrients with the Scores for Raw Meat

Attributes	**All characteristics**		**All characteristics without carcass values**		**All characteristics without carcass and cut dissections**	
	CV1	**CV2**	**CV1**	**CV2**	**CV1**	**CV2**
%	65,77	34,23	67,42	32,58	67,55	32,45
Carcass:						
Fat Content	-0,195	0,244				
Subcutaneous fat	-0,113	0,355				
Meat	-0,359	-0,433				
Bone	0,416	-0,112				
Cut:						
Physical dissection						
Subcutaneous fat	-0,034	0,101	-0,027	0,072		
Meat	-0,019	-0,048	-0,015	-0,046		
Bone	0,034	0,008	0,033	0,011		
Proximate						
Fat	-0,084	0,102	-0,087	0,078	-0,087	0,078
Protein	0,081	-0,168	0,106	-0,157	0,107	-0,159
Moisture	0,050	-0,091	0,043	-0,062	0,041	-0,060
Amino acids						
Alanine	0,266	-0,101	0,237	-0,021	0,238	-0,023
Glycine	0,109	-0,073	0,121	-0,061	0,123	-0,063
Valine	0,140	-0,282	0,130	-0,207	0,130	-0,208
Threonine	0,045	-0,391	0,051	-0,323	0,049	-0,322
Serine	0,152	-0,245	0,142	-0,173	0,141	-0,173
Leucine	0,324	-0,356	0,298	-0,231	0,295	-0,229
Isoleucine	0,194	0,056	0,161	0,013	0,163	0,010
Proline	0,089	-0,128	0,102	-0,110	0,103	-0,112
Hydroxyproline	0,064	-0,095	0,082	-0,092	0,083	-0,094
Methionine	-0,091	-0,330	-0,047	-0,338	-0,048	-0,337
Aspartic acid	0,072	-0,283	0,096	-0,254	0,097	-0,256
Phenylalanine	0,123	-0,304	0,128	-0,243	0,128	-0,244
Glutamic acid	0,157	-0,212	0,142	-0,142	0,143	-0,134
Lysine	-0,011	-0,673	0,049	-0,632	0,048	-0,633
Tyrosine	-0,074	-0,110	-0,046	-0,134	-0,044	-0,136
Arginine	0,120	-0,064	0,110	-0,027	0,111	-0,028
Histidine	0,128	-0,349	0,160	-0,313	0,158	-0,312
Tryptophan	0,229	-0,186	0,231	-0,129	0,229	-0,128
Cystine	0,117	0,035	0,045	0,120	0,043	0,123
Fatty acids						
14:0	-0,100	0,260	-0,137	0,245	-0,134	0,243
16:0	0,046	0,115	0,041	0,107	0,040	0,108
16:1	-0,207	0,141	-0,247	0,140	-0,248	0,141
18:0	-0,053	-0,003	-0,023	-0,042	-0,022	-0,043
18:1	-0,055	0,078	-0,051	0,053	-0,049	0,051
18:2	-0,657	0,377	-0,708	0,313	-0,708	0,317
20:4	-0,149	-0,052	-0,180	-0,017	-0,182	-0,014
Cholesterol	-0,433	0,110	-0,459	0,069	-0,455	0,066
Vitamins						
Thiamin	-0,122	0,013	-0,116	-0,013	-0,116	-0,013
Riboflavin	0,073	-0,182	0,083	-0,154	0,083	-0,155
Nicotinamide	-0,213	0,036	-0,239	0,033	-0,243	0,039
Pyridoxine	0,478	-0,090	0,513	-0,057	0,515	-0,061
Folic acid	0,649	-0,100	0,679	-0,042	0,679	-0,044
Cyanocobalamin	0,342	-0,205	0,351	-0,137	0,352	-0,139
Biotin	0,487	0,119	0,497	0,142	0,500	0,137
Pantothenic acid	-0,144	0,157	-0,239	0,225	-0,237	0,224
Minerals						
Phosphorus	-0,019	-0,171	-0,013	-0,151	-0,015	-0,150
Calcium	-0,073	-0,000	-0,044	-0,042	-0,050	-0,035
Magnesium	-0,156	-0,132	0,155	-0,091	0,156	-0,092
Potassium	0,034	-0,206	0,048	-0,184	0,048	-0,184
Sodium	0,051	-0,265	0,071	-0,237	0,072	-0,239
Copper	-0,219	0,150	-0,199	0,075	-0,200	0,077
Zinc	0,107	-0,163	0,103	-0,118	0,104	-0,119
Manganese	-0,226	-0,307	-0,217	-0,295	-0,217	-0,295
Iron	0,712	0,010	0,731	0,056	0,733	0,051

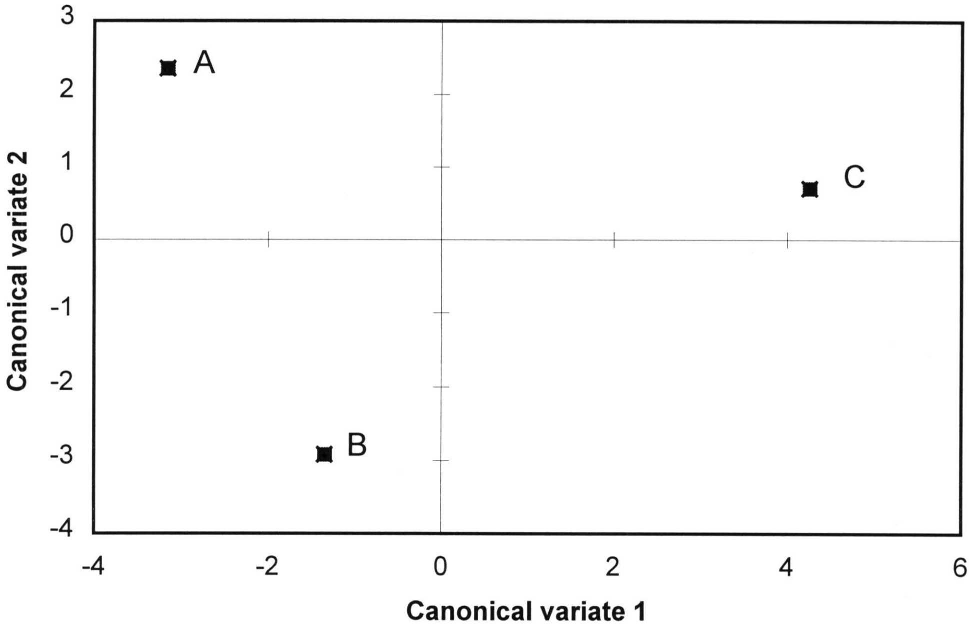

Fig. 6.3: Plot of CVA2 mean scores of three age groups[1]
(Raw)

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C age group ≥ 8 permanent incisors

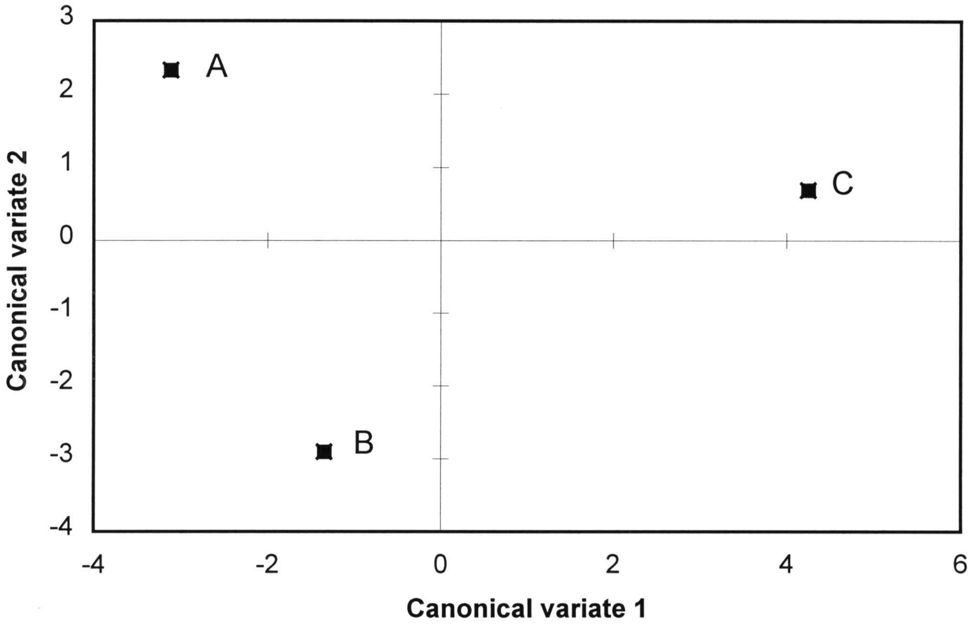

Fig. 6.4: Plot of CVA3 mean scores of three age groups[1]
(Raw)

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C age group ≥ 8 permanent incisors

TABLE 6.3

Least Square Mean Values for Nutrient Attributes for Beef Obtained from Three Age Groups (n = 18) (g/100 g edible portion with the exception of minerals mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

Attribute	Raw			Cooked		
	A-age	B-age	C-age	A-age	B-age	C-age
Cut:						
Physical dissection						
Subcutaneous fat	7,18	6,41	6,97			
Meat	86,62^{a}	86,46^{a}	85,06^{b}			
Bone	13,35^{a}	13,54^{a}	14,94^{b}			
Proximate						
Fat	19,79	19,90	20,07	24,07	21,14	19,63
Protein	18,16	18,65	18,44	26,16^{a}	26,27^{a}	27,29^{b}
Moisture	61,13	60,95	60,65	51,27^{a}	51,15^{a}	50,30^{b}
Amino acids						
Alanine	1,02^{a}	1,12^{ab}	1,17^{b}	1,48^{a}	1,53^{a}	1,70^{b}
Glycine	1,04	1,15	1,19	1,51^{a}	1,57^{a}	1,71^{b}
Valine	0,66^{a}	0,77^{b}	0,75^{b}	1,00^{a}	1,04^{a}	1,17^{b}
Threonine	0,66^{a}	0,77^{b}	0,72^{a}	0,98^{a}	1,08^{b}	1,10^{b}
Serine	0,38	1,37	1,44	0,93^{a}	1,02^{b}	1,03^{b}
Leucine	1,17^{a}	1,38^{b}	1,39^{b}	1,78^{a}	1,95^{ab}	2,10^{b}
Isoleucine	0,64	0,69	0,72	0,99	0,95	1,08
Proline	0,79	0,89	0,89	1,16^{a}	1,23^{b}	1,29^{c}
Hydroxyproline	0,28	0,32	0,32	0,38^{a}	0,42^{a}	0,47^{b}
Methionine	0,25	0,30	0,25	0,36	0,43	0,42
Aspartic acid	1,41	1,56	1,52	2,05	2,20	2,25
Phenylalanine	0,57	0,66	0,64	0,86	0,93	0,96
Glutamic acid	2,29	2,53	2,52	3,36^{a}	3,57^{ab}	3,71^{b}
Lysine	1,45^{a}	1,98^{b}	1,69^{a}	2,10^{a}	2,78^{b}	2,45^{b}
Tyrosine	0,48	0,52	0,50	0,76	0,77	0,73
Arginine	1,09	1,16	1,19	1,59^{a}	1,61^{a}	1,75^{b}
Histidine	0,47	0,59	0,55	0,63	0,69	0,78
Tryptophan	0,17	0,18	0,18	0,24	0,26	0,27
Cystine	0,20	0,21	0,21	0,28	0,28	0,30
Fatty acids						
14:0	0,43	0,38	0,41	0,47	0,37	0,43
16:0	3,58^{a}	3,58^{a}	3,93^{b}	3,91^{a}	3,94^{a}	4,24^{b}
16:1	0,63	0,60	0,55	0,46	0,44	0,50
18:0	2,95	2,89	2,89	3,13	3,19	3,00
18:1	6,00	6,38	6,48	6,57	6,76	6,74
18:2	0,55^{a}	0,34^{b}	0,20^{c}	0,45^{a}	0,27^{b}	0,17^{b}
20:4	0,03	0,03	0,02	0,03	0,03	0,03
Cholesterol	70,97	68,07	61,18	88,06	89,10	82,42
Vitamins						
Thiamin	0,116	0,110	0,100	0,135	0,105	0.094
Riboflavin	0,104	0,115	0,112	0,122	0,105	0,122
Nicotinamide	4,62	4,33	4,05	4,10	4,09	4,20
Pyridoxine	0,252	0,.295	0,387	0,382	0,373	0,383
Folic acid	9,02^{a}	10,89^{a}	15,03^{b}	12,85	14,01	14,20
Cyanocobalamin	1,34	1,58	1,77	1,97	2,10	2,13
Biotin	1,99^{a}	1,95^{a}	2,55^{b}	1,95	2,06	2,03
Pantothenic acid	0,322	0,288	0,265	0,258	0,255	0,252
Minerals						
Phosphorus	160	167	158	165^{a}	181^{b}	165^{a}
Calcium	13,7	14,8	14,3	12,3	15,1	14,5
Magnesium	18,2	19,0	20,0	23,0	22,6	22,9
Potassium	272	293	278	260	280	277
Sodium	88	100	95	79^{a}	95^{b}	93^{b}
Copper	0,229	0,165	0,141	0,121	0,164	0,145
Zinc	3,28	3,59	3,53	4,42	5,03	4,90
Manganese	0,014	0,017	0,012	0,018	0,057	0,023
Iron	0,94	1,08	1,94	1,96^{a}	2,54^{b}	2,76^{b}

^{abc} Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

* $p \leq 0,05$ ** $p \leq 0,01$ ***$p \leq 0,001$

TABLE 6.4
Canonical Variate Percentage Variation of the First Two Canonical Variates of the Three Age Groups and the Correlation Coefficients of the Nutrients with the Scores for Cooked Meat

Attribute	CV1	CV2
%	*58,44*	*41,56*
Proximate		
Fat	-0,165	-0,018
Protein	0,257	-0,067
Moisture	0,110	0,051
Amino acids		
Alanine	0,429	-0,187
Glycine	0,318	-0,046
Valine	0,459	-0,229
Threonine	0,383	-0,015
Serine	0,390	0,028
Leucine	0,460	-0,121
Isoleucine	0,300	-0,300
Proline	0,354	-0,006
Hydroxyproline	0,224	0,004
Methionine	0,346	0,202
Aspartic acid	0,374	0,011
Phenylalanine	0,398	0,014
Glutamic acid	0,379	-0,064
Lysine	0,410	0,398
Tyrosine	0,053	0,157
Arginine	0,335	-0,167
Histidine	0,387	-0,183
Tryptophan	0,329	-0,036
Cystine	0,225	-0,177
Fatty acids		
14:0	-0,225	-0,180
16:0	-0,065	-0,090
16:1	-0,104	-0,122
18:0	-0,063	0,071
18:1	-0,188	0,005
18:2	-0,741	0,006
20:4	-0,014	0,020
Cholesterol	-0,198	0,186
Vitamins		
Thiamin	-0,439	-0,076
Riboflavin	-0,037	-0,252
Nicotinamide	0,117	-0,114
Pyridoxine	-0,100	-0,174
Folic acid	0,377	0,066
Cyanocobalamin	0,237	0,079
Biotin	0,100	0,008
Pantothenic acid	-0,091	-0,091
Minerals		
Phosphorus	0,098	0,250
Calcium	0,132	0,138
Magnesium	0,051	-0,103
Potassium	0,206	0,171
Sodium	0,424	0,292
Copper	0,129	0,120
Zinc	0,231	0,124
Manganese	0,299	-0,081
Iron	0,514	0,052

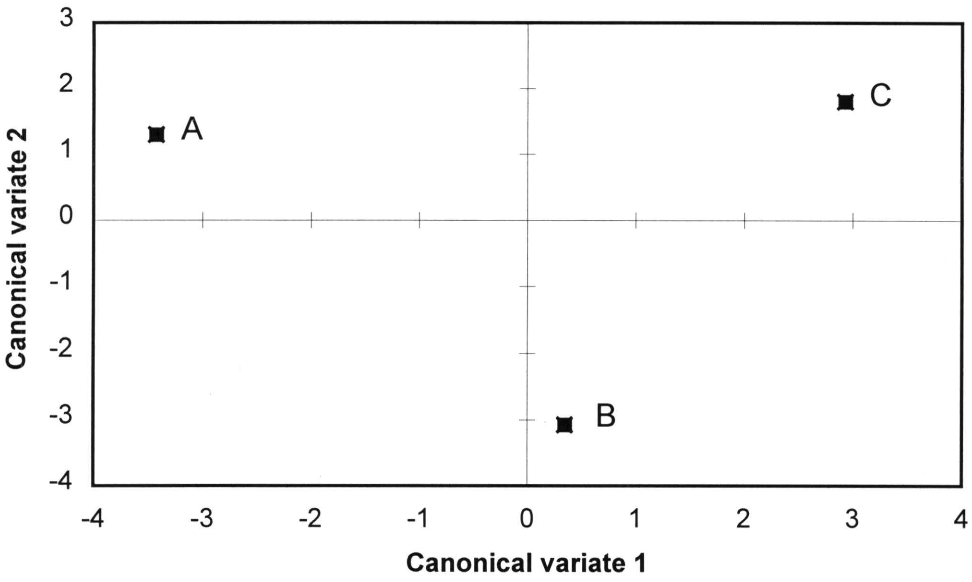

Fig. 6.5: Plot of CVA3 mean scores of three age groups[1] (Cooked)

[1] A-age group – no permanent incisors; B-age group – 2 permanent incisors; C age group ≥ 8 permanent incisors

Leucine increased significantly ($p \leq 0,05$) with age in the carcass, where the A-age group carcasses contained less than the C-age group (8 tooth). C-age group (8 tooth) carcasses contained significantly ($p \leq 0,01$) more alanine and valine than those from A- (0 tooth) and B- (2 tooth) age groups. However, thiamin did not differ significantly between carcasses of the three age groups.

Discussion of results of discrimination between ages (raw and cooked)

Consumers usually consume red meat in a cooked form and heat alters connective tissue and myofibrillar proteins (Barton-Gade *et al.*, 1988), therefore the focus of the discussion will be on the results for the raw cuts that are similar to those of the cooked cuts. Raw nutrient values provide base-line information for comparison of results i.e. between countries, to evaluate the effect of change in production on nutrient composition (Ono *et al.*, 1984).

Iron was higher in the B- and C-age groups of animals compared to A-age in both raw and cooked cuts. This finding could be explained by the fact that polyvalent metals such as iron, zinc and magnesium accumulate with age and are among the major cross linkage agents in living organisms (Bjorkstein, 1968). Increased muscle pigment concentration with increased age has also been reported (Shorthose, 1992).

Kotula & Lusby (1982) also reported an increase with age in iron from 2 mg/100 g at 12 months to 3,73 mg/100 g at 72 months. This finding is highly significant as iron-deficiency anaemia (reduced amounts of haemoglobin of which iron is an essential component in the blood) is the most widespread nutritional disease in the world today (Scrimshaw, 1993). It is linked with impaired development and learning ability in children and decreased physical performance and resistance to infection (Anderson *et al.*, 1982). Since C-age group animals are mostly consumed in the rural areas of South Africa which is generally associated with severe iron-deficiency anaemia (more than 40% of the populations of Africa), this is an assuring finding. Meat as a source of haem iron is much better absorbed than non-haem iron as in vegetables.

Lysine is one of the nine essential amino acids for adults of the approximately 20 common amino acids found in protein. It is essential as it cannot be synthesised in adequate quantities in the human body due to that the metabolic pathways for the synthesis of the basic carbon structure does not exist in the human body. It must therefore be supplied by the diet. Lysine forms part of not only the hydroxylysine-aldehyde in the formation of intermolecular cross-links in collagen with the increased age of the animal, but is part of histidino-hydroxylysinenorleucine in mature collagen which is the major cross-link in tissues (Bailey, 1989). Increased lysine content with increased age (C-age group animals compared to A-age group animals) is therefore expected.

Furthermore linoleic acid was lower in the C-age group animals compared to A-age animals. The levels of linoleic acid in beef, a major fatty acid of the neutral fatty acids in non-ruminants, are affected by diet (Enser *et al.,* 1996) and therefore explains the low levels in C-age group animals as they mainly consist of the culling of old animals. Other changes in the amino acid composition include significant ($p \leq 0,05$) increases of leucine, alanine and valine with age in the carcass.

Discrimination by cut for raw meat

The first canonical variate (CV1) accounted for 69,9% of the total variation in the data with a large latent root of 247,5 and the second (CV2) for 20,6% with a latent root of 73,8 (should be > 1) (Table 6.5). The main discriminating characteristics between the nutrient composition for the different cuts in CV1 (horisontal) were bone (r = -0,978) and meat content (r = 0,670). These characteristics were the strongest correlated with the CV1 scores. It is evident that CV1 contrasted those cuts that contained little or no bone (with associated higher meat content) such as the fillet, silverside and thick flank (negative scores), with cuts containing a high bone content such as the shins, brisket, wing rib and loin (positive scores). Figure 6.6 is a graphical representation of the CV mean scores, and the results are given in Table 6.6.

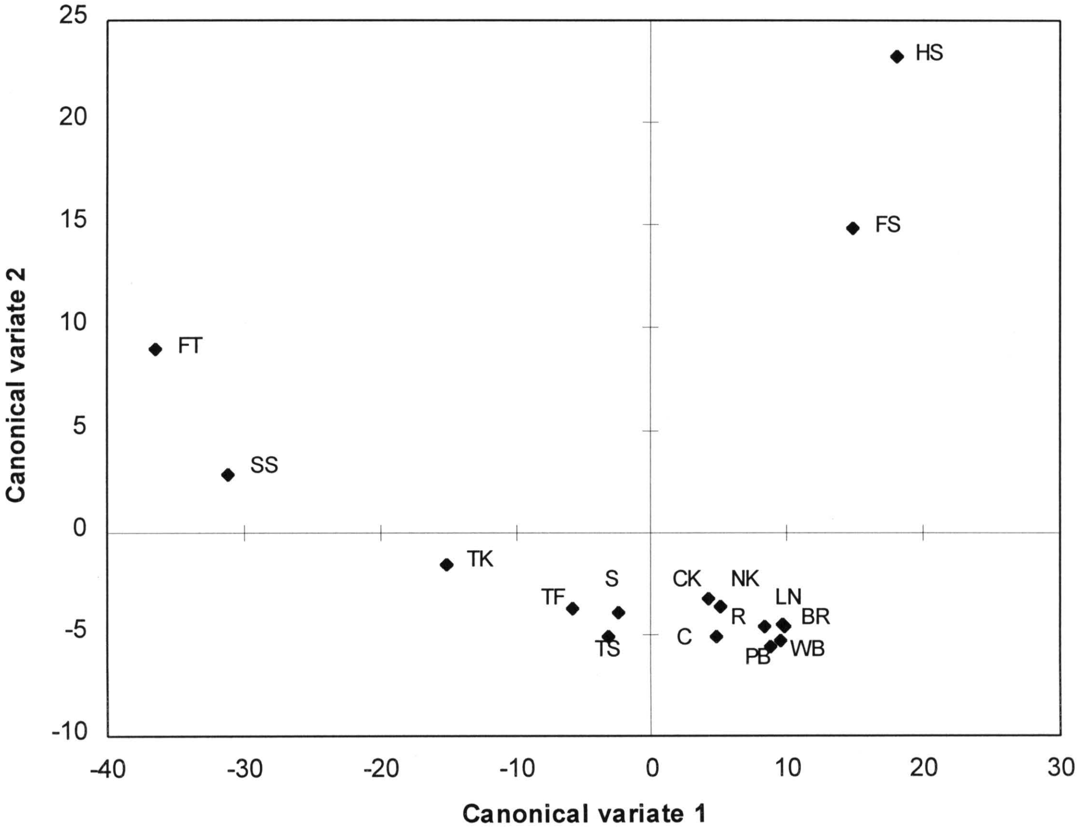

**Fig. 6.6: Plot of CVA1 mean scores of various cuts[1]
(Raw)**

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[1] PB – Prime rib, LN – Loin, WB – Wing rib, RP – Rump, FT – Fillet, SS – Silverside, TS – Topside, TK – Thick flank, CK – Chuck, BR – Brisket, NK – Neck, SH – Shoulder, TF – Thin flank, FS – Fore shin, HS – Hind shin, CC – Carcass

TABLE 6.5

Canonical Variate Percentage Variation of the First Two Canonical Variates of the 15 Raw Cuts and the Correlation Coefficients of the Nutrients with the Scores

Attribute	**All characteristics**		**All characteristics without carcass values**		**All characteristics without carcass and cut dissections**	
	CV1	CV2	CV1	CV2	CV1	CV2
%	69,19	20,62	68,81	22,36	42,27	27,41
Carcass:						
Fat Content	0,002	-0,004				
Subcutaneous fat	0,003	-0,005				
Meat	-0,009	0,007				
Bone	0,003	0,001				
Cut:						
Physical dissection						
Subcutaneous fat	-0,156	0,567	-0,086	0,522		
Meat	0,670	0,701	0,715	0,668		
Bone	-0,979	-0,156	-0,990	-0,077		
Proximate						
Fat	-0,413	0,483	-0,367	0,469	-0,182	0,788
Protein	0,183	-0,449	0,144	-0,429	0,052	-0,564
Moisture	0,355	-0,399	0,314	-0,378	0,182	-0,702
Amino acids						
Alanine	-0,111	-0,323	-0,125	-0,332	-0,255	-0,247
Glycine	-0,369	-0,539	-0,400	-0,531	-0,605	-0,282
Valine	0,206	-0,093	0,202	-0,112	0,107	-0,207
Threonine	0,255	-0,169	0,236	-0,172	0,228	-0,391
Serine	0,079	-0,301	0,061	-0,299	-0,018	-0,411
Leucine	0,236	-0,120	0,220	-0,131	0,158	-0,312
Isoleucine	0,264	-0,077	0,260	-0,088	0,219	-0,260
Proline	-0,295	-0,520	-0,327	-0,513	-0,527	-0,321
Hydroxyproline	-0,465	-0,561	-0,500	-0,542	-0,679	-0,248
Methionine	0,157	-0,073	0,161	-0,083	0,168	-0,211
Aspartic acid	0,206	-0,272	0,183	-0,272	0,131	-0,453
Phenylalanine	0,199	-0,170	0,184	-0,177	0,107	-0,332
Glutamic acid	0,139	-0,269	0,116	-0,266	0,022	-0,437
Lysine	-0,009	-0,065	-0,007	-0,070	-0,047	-0,102
Tyrosine	0,014	0,016	0,012	0,014	0,034	0,016
Arginine	0,043	-0,503	0,005	-0,486	-0,162	-0,559
Histidine	0,121	0,042	0,128	0,036	0,188	-0,024
Tryptophan	0,262	-0,031	0,268	-0,040	0,328	-0,238
Cystine	0,151	-0,129	0,137	-0,102	0,075	-0,268
Fatty acids						
14:0	-0,277	0,404	-0,246	0,389	-0,107	0,643
16:0	-0,373	0,496	-0,326	0,480	-0,154	0,789
16:1	-0,283	0,205	-0,263	0,179	-0,156	0,486
18:0	-0,296	0,636	-0,244	0,625	-0,062	0,833
18:1	-0,391	0,349	-0,352	0,332	-0,212	0,659
18:2	-0,060	0,131	-0,059	0,128	-0,010	0,175
20:4	0,142	-0,111	0,093	-0,090	0,059	-0,194
Cholesterol	-0,221	-0,027	-0,219	-0,029	-0,312	0,053
Vitamins						
Thiamin	0,264	-0,189	0,241	-0,182	0,219	-0,355
Riboflavin	0,281	-0,113	0,269	-0,122	0,246	-0,310
Nicotinamide	0,249	0,163	0,260	0,157	0,472	0,055
Pyridoxine	0,088	0,020	0,087	0,015	0,125	-0,033
Folic acid	0,099	0,006	0,097	0,001	0,071	-0,044
Cyanocobalamin	0,194	-0,179	0,165	-0,173	0,083	-0,379
Biotin	0,245	-0,113	0,221	-0,105	0,212	-0,213
Pantothenic acid	0,102	-0,155	0,098	-0,164	0,026	-0,236
Minerals						
Phosphorus	0,489	-0,071	0,480	-0,073	0,519	-0,428
Calcium	-0,441	0,266	-0,425	0,300	-0,198	0,509
Magnesium	0,294	-0,027	0,292	-0,024	0,353	-0,276
Potassium	0,464	-0,017	0,462	-0,007	0,527	-0,338
Sodium	-0,300	-0,450	-0,337	-0,439	-0,655	-0,311
Copper	0,028	0,090	0,035	0,074	0,060	0,074
Zinc	-0,256	-0,158	-0,282	-0,099	-0,591	-0,236
Manganese	-0,040	-0,060	-0,043	-0,071	-0,044	-0,025
Iron	0,071	-0,040	0,058	-0,023	0,047	-0,116

TABLE 6.6
Canonical Variate Mean Scores of Various Raw Cuts

CUT	CVA 1		CVA 2		CVA 3	
	CV1	CV2	CV1	CV2	CV1	CV2
Fillet	-36,5	9,0	-31,5	8,9	-7,6	6,0
Silverside	-31,2	2,8	-29,2	5,0	-4,2	1,5
Thick Flank	-15,1	-1,6	-14,1	-1,3	-0,6	3,0
Thin Flank	-5,8	-3,7	-6,5	-1,5	2,6	-3,2
Topside	-3,1	-5,1	-3,6	-5,0	-4,5	-0,7
Shoulder	-2,4	-4,0	-2,6	-4,3	0,4	1,0
Chuck	4,2	-3,2	4,4	-4,3	3,4	-1,1
Carcass	4,8	-5,1	3,8	-5,2	0,2	-1,0
Neck	5,2	-3,6	4,5	-4,4	4,1	-1,0
Rump	8,3	-4,7	7,0	-4,9	-3,1	-1,1
Prime Rib	8,8	-5,6	7,6	-5,6	-0,5	-3,8
Wing Rib	9,6	-5,3	8,2	-5,1	-1,0	-3,6
Loin	9,7	-4,5	8,3	-4,4	-2,5	-2,9
Brisket	9,9	-4,7	8,6	-4,9	2,4	-2,2
Fore Shin	14,8	14,9	15,8	12,8	6,5	5,5
Hind Shin	18,0	23,3	19,2	22,4	5,4	3,5

Meat (r = 0,701) and subcutaneous fat (r = 0,567) content of the cut, stearic acid (18:0) (r = 0,636), hydroxyproline (r = -0,561), glycine (r = -0,539), proline (r = -0,520) and arginine (r = -0,503) discriminated mainly between the fifteen cuts in the CV2 (vertical axis) i.e. the hind and fore shins, and to a lesser extend the fillet were contrasted against the topside, prime and wing rib according to the attributes listed. The former cuts were low in subcutaneous fat, meat and stearic acid and high in glycine, hydroxyproline, proline and arginine. This finding that the shins contain low amounts of subcutaneous fat and meat is well known and accepted.

The identical nutrients made similar contributions to the second CVA procedure that excluded the carcass values and will therefore not be discussed separately (Figure 6.7). In the third CVA procedure which excluded the carcass and cut dissection values the first canonical variate (CV1) accounted for 42,3 % of the total variation in the data with a latent root of 15,2 and the second (CV2) for 27,4 with a latent root of 9,9 (should be >1).

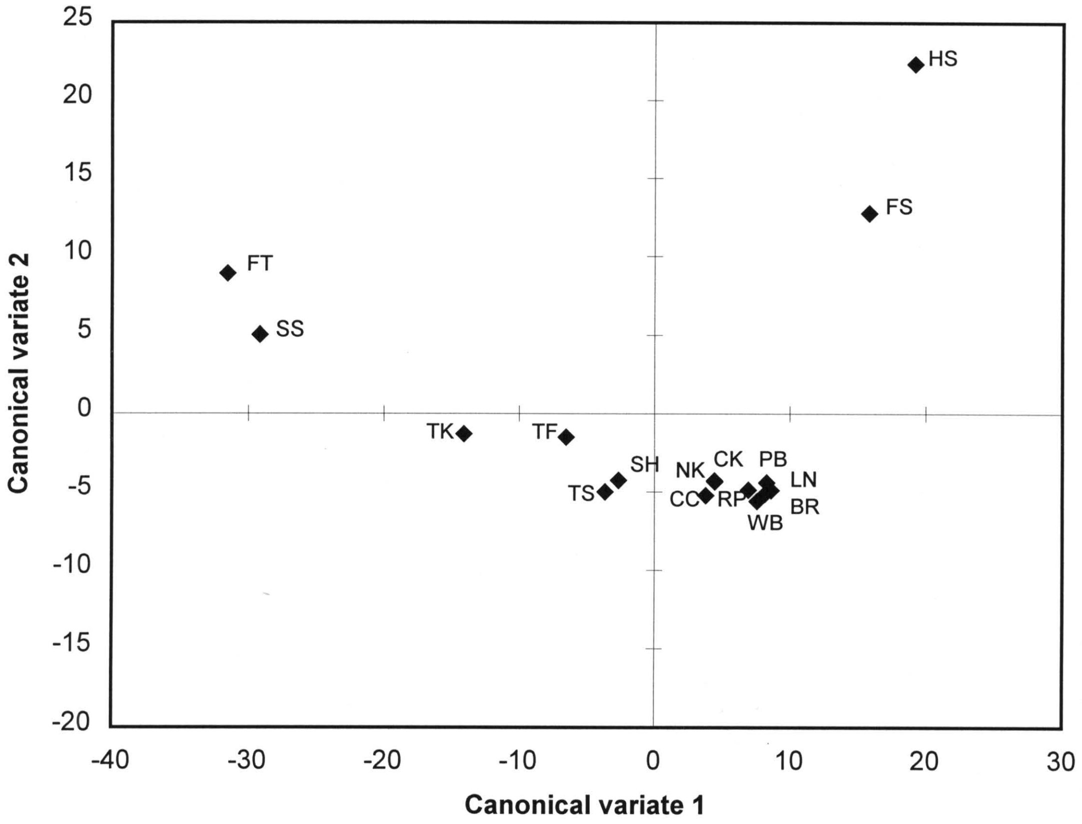

Fig. 6.7: Plot of CVA2 mean scores of various cuts[1]
(Raw)

[1] PB – Prime rib, LN – Loin, WB – Wing rib, RP – Rump, FT – Fillet, SS – Silverside, TS – Topside, TK – Thick flank, CK – Chuck, BR – Brisket, NK – Neck, SH – Shoulder, TF – Thin flank, FS – Fore shin, HS – Hind shin, CC – Carcass

The variates mainly discriminating for CVA3 (Figure 6.8) between the nutrient composition for the different cuts in CV1 were hydroxyproline (r = -0,679), glycine (r = -0,605), proline (r = -0,527), sodium (r = -0,655), zinc (r = -0,591), potassium (r = 0,527) and phosphorus (r = 0,519). Inspection of the results (Figure 6.8) shows that the neck, shins and chuck were contrasted against the fillet, topside and silverside according to the attributes listed. The former cuts were low in potassium and phosphorus and high in hydroxyproline, proline, glycine, sodium and copper, as opposed to the latter cuts.

The main variates that discriminated between groups in CV2 for the different cuts were the proximate analyses results (fat with r = 0,788, moisture with r = -0,702 and protein with r = -0,564), arginine (r = -0,559), fatty acids (myristic (14:0) with r = 0,643, palmitic (16:0) with r = 0,789, stearic (18:0) with r = 0,833 and oleic (18:1) with r = 0,659) and calcium (r = 0,509).

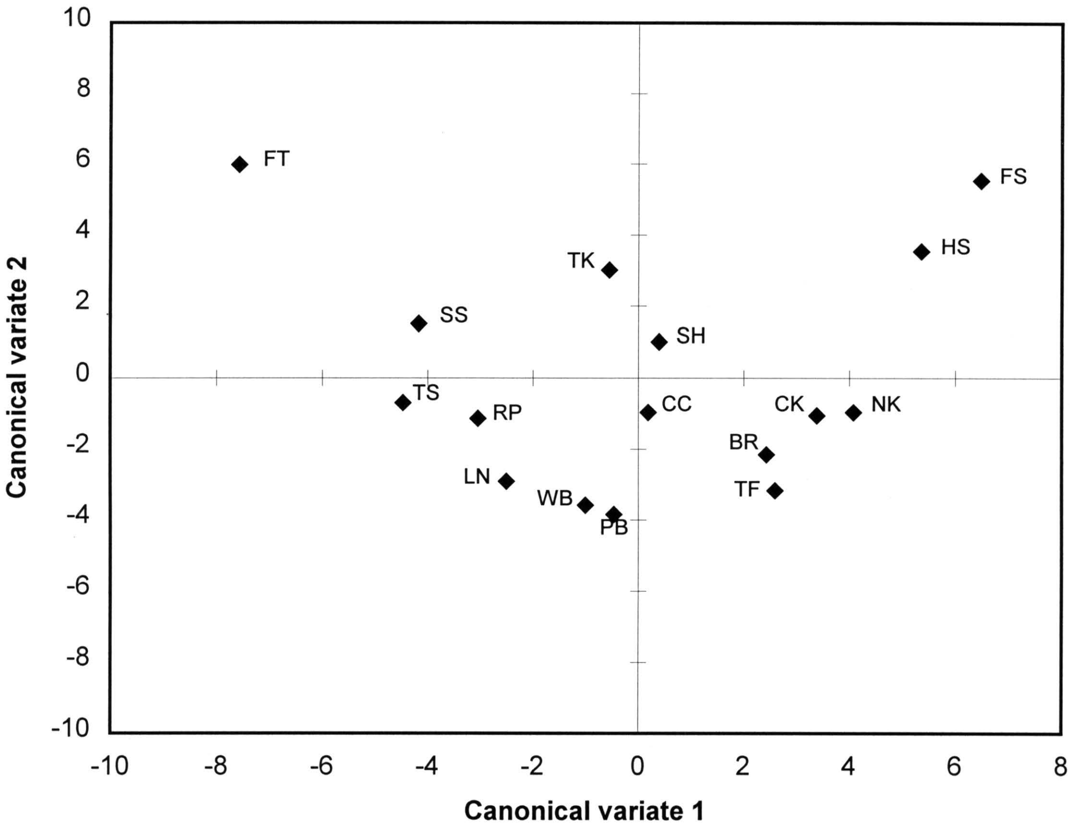

**Fig. 6.8: Plot of CVA3 mean scores of various cuts[1]
(Raw)**

[1] PB – Prime rib, LN – Loin, WB – Wing rib, RP – Rump, FT – Fillet, SS – Silverside, TS – Topside, TK – Thick flank, CK – Chuck, BR – Brisket, NK – Neck, SH – Shoulder, TF – Thin flank, FS – Fore shin, HS – Hind shin, CC - Carcass

The results (Figure 6.8) shows that the fillet, thick flank and shins were contrasted against the prime rib, wing rib and thin flank. The former cuts are low in fat, various fatty acids as described and calcium and high in protein, moisture and arginine, as opposed to the latter cuts. The results can be summarised as follows: the cuts that contained little or no bone (with the associated higher meat content) such as the fillet, silverside and thick flank were contrasted against the cuts with a high bone content such as the shins and brisket. When the carcass and cut dissections were excluded the fillet, topside and silverside were contrasted against the neck, shins and chuck with the former being high in potassium and phosphorus and low in hydroxyproline, proline, glycine, sodium, copper and zinc, as opposed to the other cuts mentioned.

In the CV2 the shins were contrasted against the topside, prime and wing rib with the former being low in subcutaneous fat, meat and stearic acid and high in glycine, hydroxyproline, proline and arginine, as opposed to the cuts listed. In CV2 for CVA3 the fillet, thick flank and shins were contrasted against the prime rib, wing rib and thin flank. The former cuts were low in proximate fat, all the saturated fatty acids plus oleic acid and calcium and high in protein, moisture and arginine, as opposed to the latter cuts. The differences in subcutaneous fat and meat between the various cuts is to be expected and are largely due to the growth patterns of meat due to differences in function (Berg *et al.*, 1976).

The discrimination between the cooked cuts

In the CVA, the first canonical variate (CV1) accounted for 36,4% (Table 6.5) of the total variation in the data with a latent root of 19,2 and the second (CV2) for 28,8% with a latent root of 15,2 (should be >1). The main discriminating variates between the nutrient composition for the different cuts in CV1 were hydroxyproline (r = -0,681), glycine (r = -0,510), phosphorus (r = 0,636), potassium (r = 0,629) and magnesium (r = 0,594). The CV mean scores are presented in both Figure 6.9 and Table 6.7. Inspection of the graphical presentation of the results showed that the shins, thin flank and neck were contrasted against the fillet, topside, loin and rump according to nutrient content with the former group of cuts being low in phosphorus, potassium and magnesium and high in hydroxyproline and glycine.

The variates that mainly discriminated between groups in CV2 for the different cuts were the calcium (r = -0,738), proximate fat (r = -0,680), moisture (r = 0,651) and fatty acids (16:0 with r = -0,669, 18:0 with (r = -0,697 and 18:1 with r = -0,567). Inspection of the graphical presentation of the results (Figure 6.9) shows that the fillet, thick flank, silverside and shins were contrasted against the loin, chuck, wing and prime rib according to nutrient content with the former being low in fat, various fatty acids as described and calcium and high in moisture, as opposed to the latter cuts.

TABLE 6.7
Canonical Variate Percentage Variation of the First Two Canonical Variates of the 15 Cooked Cuts and the Correlation Coefficients of the Nutrients with the Scores

Group	**CV1**	**CV2**
%	36,44	28,84
Proximate		
Fat	-0,113	-0,680
Protein	0,251	0,397
Moisture	0,061	0,651
Amino acids		
Alanine	0,051	0,212
Glycine	-0,510	0,188
Valine	0,337	0,175
Threonine	0,418	0,270
Serine	0,206	0,270
Leucine	0,408	0,247
Isoleucine	0,422	0,188
Proline	-0,349	0,236
Hydroxyproline	-0,681	0,190
Methionine	0,315	0,105
Aspartic acid	0,354	0,304
Phenylalanine	0,347	0,240
Glutamic acid	0,322	0,292
Lysine	0,267	0,123
Tyrosine	0,208	0,005
Arginine	0,151	0,420
Histidine	0,428	0,128
Tryptophan	0,453	0,208
Cystine	0,278	0,221
Fatty acids		
14:0	-0,069	-0,487
16:0	-0,103	-0,669
16:1	-0,200	-0,373
18:0	0,028	-0,697
18:1	-0,216	-0,567
18:2	0,055	-0,085
20:4	0,049	0,032
Cholesterol	-0,085	0,029
Vitamins		
Thiamin	0,113	0,059
Riboflavin	0,117	0,057
Nicotinamide	0,469	0,028
Pyridoxine	0,291	0,091
Folic acid	0,075	-0,001
Cyanocobalamin	0,119	0,173
Biotin	0,236	0,171
Pantothenic acid	0,108	0,289
Minerals		
Phosphorus	0,636	0,208
Calcium	0,268	-0,738
Magnesium	0,594	0,144
Potassium	0,629	0,290
Sodium	-0,424	0,157
Copper	0,253	0,371
Zinc	-0,415	0,053
Manganese	0,095	0,044
Iron	0,276	0,267

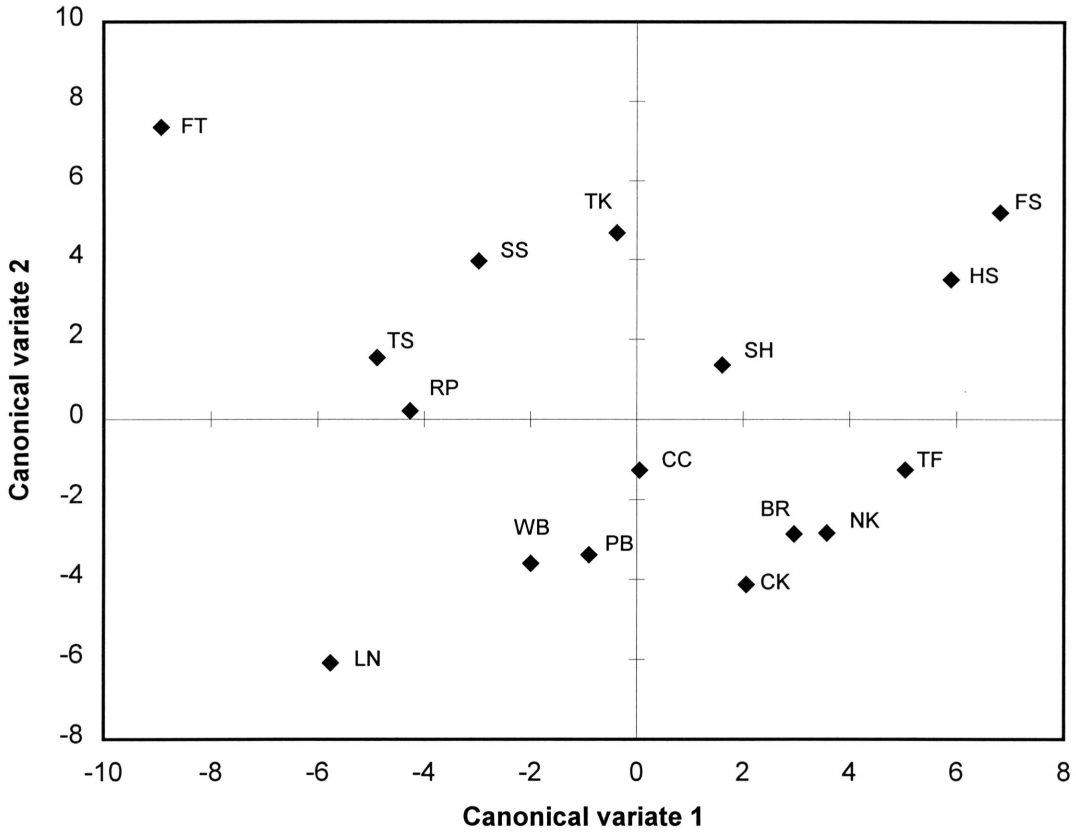

**Fig. 6.9: Plot of CVA mean scores of various cuts[1]
(Cooked)**

[1] PB – Prime rib, LN – Loin, WB – Wing rib, RP – Rump, FT – Fillet, SS – Silverside, TS – Topside, TK – Thick flank, CK – Chuck, BR – Brisket, NK – Neck, SH – Shoulder, TF – Thin flank, FS – Fore shin, HS – Hind shin, CC – Carcass

Discussion of results of discrimination between cuts (raw and cooked)

Raw cuts with the carcass and cut dissections included in the CVA, cuts that contained little or no bone such as the fillet (with the associated higher meat content), silverside and thick flank were contrasted against the cuts with a high bone content such as the shins and brisket. Differences between the various cuts is to be expected and are largely due to the growth patterns of meat, bone and fat tissues and is mostly determined by function (Berg et al., 1976).

As cooked meat represent meat as eaten by the consumer, these results will be the focus of the discussion. The shins and neck (for both raw and cooked cuts) were contrasted against the fillet and topside with the former low in phosphorus, potassium and magnesium and high in hydroxyproline and glycine. The lower reported values for phosphorus, potassium and magnesium in the shins and neck compared to the fillet and topside are similar to the results of Kotula and Lusby (1982). They reported that the concentrations of all minerals varied between the five muscles they studied, with the lowest amount of potassium and magnesium in the most active muscle i.e. the neck in this study. Hydroxyproline content is used to determine the total collagen content of the respective muscles (Boccard *et al.*, 1979) as well as their solubility (Hill, 1966; Bergman & Loxley, 1963). Collagen characteristics vary between meat within a carcass, between carcasses for individual muscles, with animal age and breeds and with cooking conditions (Harris *et al.*, 1976). The differences are as expected with shins and neck containing on average the highest amount of collagen in the carcass and the fillet the least. As glycine forms a part of the collagen helix it is evident that it will follow a similar pattern as hydroxyproline.

In CV2 the fillet, thick flank and shins were contrasted against the prime and wing rib with the former being low in fat, various fatty acids (palmitic, stearic and oleic acids) and calcium and high in moisture, as opposed to the latter cuts. The inverse relationship between moisture and fat content within the carcass is known and is similar to the findings of McKeith *et al.* (1985). The relationship between fat and saturated fatty acids (palmitic, stearic and oleic acids) are explained by to the fact that fatty acids from external fat are more saturated than those from intramuscular fat (Anderson *et al.*, 1971; Marmer *et al.*, 1984). Cuts that contain little external fat such as the fillet, thick flank and shins will therefore contain less saturated fatty acids. However, these differences in fat and fatty acids between the different cuts found in this study differ from those of Rhee *et al.* (1988) who reported similar fat and fatty acid contents for LD, PM, SM and ST. In this study the PM is similar to the fillet and the LD similar to the loin, prime and wing rib.

The results by Rhee *et al.* (1988) were obtained with meat that was trimmed of all outside fat prior to the analyses whereas in the present study all cuts were analysed with associated subcutaneous fat. However, removal of all subcutaneous fat prior to cooking and cooking with 0,64 cm external fat trim had no effect on fatty acid percentages according to Smith *et al.* (1989).

Determination of the most reliable cut to predict nutrient content

Owing that the composition of beef is dynamic and changes over time with a subsequent change in its nutrient composition, it was important to determine the most reliable cut or cuts to predict the nutrient content of South African beef. This will have the advantage of analysing only a single cut to monitor the values for the nutrient content of beef. Changes in the nutrient composition of such a cut can be used as a timely warning to the industry to undertake the next large scale nutrient composition analysis of beef. The results of the distances of the various cuts from the carcass value with CVA are presented in Tables 6.8. The data was subjected to three CVA procedures as tabulated.

In studying the table the neck and chuck emerged as the cuts that were the closest in composition to that of the carcass when the physical dissected tissues of subcutaneous fat, meat and bone of both the carcass and cuts respectively were included in the analyses with raw cuts. However, when the physically dissected tissues of subcutaneous fat, meat and bone were excluded, the shoulder was the closest in nutrient composition of the raw carcass. The prime rib was the closest with the shoulder second to the nutrient composition of the cooked cuts of the carcass.

The significance of this finding is that should the need in future arise to analyse beef for nutrient content for legislation purposes, or to make sure from time to time that the results of this study on nutrient composition of South African beef is still valid, only one or two cuts i.e. the neck or chuck need to be analysed in order to describe the nutrient content of the carcass.

CONCLUSIONS AND RECOMMENDATIONS

The physical composition (proportions of meat, fat and bone) of the carcass and the various cuts had the most discriminating effect on the difference between the three age groups (carcass meat content). However, when the data were analysed without the physical analyses of the carcasses and cuts, lysine and iron were the nutrients that were the most discriminating between the three age groups. Both nutrients were higher in the C-age group

TABLE 6.8
CVA Intergroup Distances for the First Two Dimensions Closest to Carcass Values for Nutrient Content (Attributes Logged)

Ranking Of Distances	**RAW**			**COOKED**
	With Physical Dissections	**Without Carcass Dissections**	**Without Carcass and Cut Dissections**	**Without Carcass and Cut Dissection**
1	Neck 1,54	Neck 1,08	Shoulder 1,99	Prime rib 2,32
2	Chuck 1,97	Chuck 1,12	Brisket 2,54	Shoulder 3,06
3	Rump 3,52	Rump 3,15	Wing rib 2,88	Wing rib 3,10
4	Prime rib 4,05	Prime rib 3,78	Prime rib 2,95	Brisket 3,31
5	Wing rib 4,79	Wing rib 4,36	Chuck 3,20	Chuck 3,49
6	Loin 4,94	Loin 4,56	Rump 3,24	Neck 3,85
7	Brisket 5,08	Brisket 4,83	Thin flank 3,26	Rump 4,57
8	Shoulder 7,31	Shoulder 6,53	Loin 3,32	Thin flank 4,99
9	Topside 7,91	Topside 7,45	Neck 3,89	Topside 5,68
10	Thin flank 10,64	Thin flank 10,99	Thick flank 4,04	Thick flank 5,97
11	Thick flank 20,22	Thick flank 18,33	Topside 4,67	Silverside 6,05
12	Fore shin 22,33	Fore shin 21,64	Silverside 5,01	Hind shin 7,54
13	Hind shin 31,28	Hind shin 31,56	Hind shin 6,85	Loin 7,55
14	Silverside 13,85	Silverside 34,52	Fore shin 9,05	Fore shin 9,35
15	Fillet 43,57	Fillet 38,07	Fillet 10,41	Fillet 12,45

animals than in A- or B-age animals for both raw and cooked cuts. Vorster et al. (*s. a.*) tabulated the daily intake of iron of South African black, coloured and Indian girls and women as less than the Recommended dietary allowance (RDA) of the USA Food and Nutrition Board. In some instances their daily intakes of iron were even less than 50% of the RDA. Therefore the higher iron content in C-age group animals, is of significance, as a low iron intake over time leads to iron-deficiency anaemia, one of the most widespread nutritional diseases in the world today. Due to the lower market price of C-age animals, it improves affordability for low-income specific population groups, and can be recommended to form part of their diet, to meet this dietary need. Lysine forms part of the cross-linking of collagen which is age associated and, as one of the nine essential amino acids for adults, C-age group animals, contrary to common belief (that it is of inferior quality), can be recommended to form part of a balanced diet. This finding is of great significance to health workers. This good source of iron and essential amino acids can be used to prevent iron-deficiency anaemia and essential amino acid deficiency is cost effective. Due to the inverse relationship of price with age of the animal in South Africa, meat from older animals cost less than the meat from younger animals.

Without the physical composition data for the carcasses and cuts, the attributes that discriminated between the different cuts within the same carcass were hydroxyproline, glycine and some minerals. Because cuts differ in the amount of collagen, hydroxyproline and glycine as part of collagen, will vary accordingly. Differences in the amounts of phosphorus, potassium and magnesium in the cuts are probably explained by the activity of the muscles. Differences in fat content (subcutaneous and proximate), meat, moisture, various fatty acids (palmitic, stearic and oleic acids) and calcium were also found between the different cuts. The inverse relationship between moisture and fat content within the carcass is known.

In recent years health professionals have recommended that foods high in saturated fat and total fat be avoided to decrease plasma cholesterol in individuals with a high risk of coronary heart disease and stroke (Grundy, 1991). Therefore the inclusion of cuts low in both fat and saturated fatty acids such as the fillet, thick flank and shins should be further investigated, as meat by its content of minerals and vitamins, plays a very important role in nutrition (Dumas, 1992).

The neck and chuck emerged as the cuts that were the closest in composition to that of the carcass when the physical dissected tissues of subcutaneous fat, meat and bone of both the carcass and cuts respectively, were included in raw cuts. However, when the physical dissected tissues of subcutaneous fat, meat and bone were excluded the shoulder was the closest in nutrient composition to the raw carcass and the prime rib the closest with the shoulder second to the nutrient composition of the cooked cuts of the carcass. Should the need arise to analyse beef for nutrient content from time to time to monitor the results of this study, these cuts can successfully be used to describe nutrient content, saving time and analytical costs as the whole carcass need not be analysed again. These results would not have emerged had only ANOVA been used to analyse the data. Multivariate analyses, in this case CVA, is essential to interpret such large data sets.

Since some consumers are already demanding meat with no visible subcutaneous fat, it is recommended that subcutaneous fat of South African beef for the various age and fatness groups be analysed. It will enable to express the results of this study on a lean meat only basis, which is in line with the more recent tables of the American and British nutrient profiles of meat.

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7

Conclusions and Recommendations

A systematic description of the physical composition, eating and nutritional quality characteristics of South African beef has not been attempted up to now. This study of beef animals included the three different age groups (representing the full variation in fatness within each age group) and cuts from carcasses as obtained in the commercial market. To ensure that the effect of animal age (as defined in the current South African classification system) was determined, the percentage chemical fat of the carcass was used as covariant in all the statistical analyses.

The bone and meat content between the different cuts within the same carcass varied considerably. In general, the relative meat content decreased and bone content increased in older animals (C age). A large variation in compositional and chemical characteristics for the various cuts for the three age groups was observed. On average, the fore and hind shins contained the lowest amount of chemical fat, followed by the fillet and thick flank.

Tenderness, residue and collagen solubility of all cuts decreased significantly (although not linearly) with animal age, with collagen solubility the largest discriminant between the three age groups. Animal age did not have a significant effect on the collagen content of muscles. As expected, the tenderness characteristics of primal cuts within the same carcass varied considerably, with collagen content and shear force resistance as the largest discriminant between the cuts. When studying the flavour characteristics, flavour intensity was the largest discriminant between the three age groups and its intensity or importance in discriminating declined with age. The commonly accepted belief that older animals have more flavour than those which are young is refuted in this study, as well as the differences between muscles, specifically the fillet which is described as relatively lacking in flavour. In general, the initial impression of juiciness decreased and cooking losses increased (although not linearly) with increased age, irrespective of the muscle. Sustained juiciness increased with increased age. Cuts cooked according to a dry heat cooking method were more juicy (both initial and sustained) than those cooked according to a moist heat cooking method.

Concerning nutrient content of raw beef, the physical composition (proportions of meat, fat and bone) of the carcass and the various cuts had the most discriminating effect on the difference between the three age groups (carcass meat content). However, when the nutritional data were analysed with the results of the physical dissection of the carcasses and cuts excluded, lysine and iron were the nutrients that were the most discriminating between the three age groups. Both nutrients were higher in the C-age group animals than in A- or B-age animals. This finding was also true for the cooked cuts. Since iron-deficiency anaemia is the most widespread nutritional disease in the world today, it is reassuring to know that the animals mostly consumed by the people with severe iron-deficiency anaemia in the rural areas of South Africa, are the most adequate means to meet this need. Lysine, as one of the nine essential amino acids for adults, form part of the cross-linking of collagen which is age-associated. C-age group animals, contrary to common belief (that it is of inferior quality) can be recommended as part of a balanced diet. This finding is of great significance to health workers. This good source of iron and essential amino acids to counteract iron-deficiency anaemia and essential amino acid deficiency is cost effective. Due to the inverse relationship of price with age of the animal in South Africa, meat from older animals costs less than the meat from younger animals.

Without the physical composition data for the carcasses and cuts, the attributes that discriminated between the different cuts within the same carcass were hydroxyproline, glycine and some minerals. Because cuts differ in the amount of collagen the amount of hydroxyproline and glycine, as part of collagen, will vary accordingly. Differences in the amounts of phosphorus, potassium and magnesium in the cuts are probably explained by the activity of the muscles in the live animal. Differences in fat content (subcutaneous and proximate), meat, moisture, various fatty acids (palmitic, stearic and oleic acids) and calcium were also found between the different cuts. The inverse relationship between moisture and fat content within the carcass is known.

A large variation in compositional and chemical characteristics for the various cuts for the three age groups was observed. The compositional and chemical information can be fully utilised by the Meat Industry e.g. calculation of formulae for preparation of processed food products.

It can be recommended that because cuts that are grouped together exhibit similar traits pertaining to eating quality, in future only one of these cuts could be used and will be sufficient to describe the group's behaviour for these characteristics. It is therefore proposed that it is not necessary to discriminate between the fore and hind shins cooked as beef retail cuts of 5 cm thickness. The muscles in the wing rib or prime rib will sufficiently describe the cuts cooked as intact joints subjected to a dry heat cooking method; and that the *M. gluteobiceps* in the silverside will describe the group subjected to a moist heat cooking method. The loin cooked as beef steak retail cuts and the chuck are not included in the groupings for the determination of tenderness characteristics. The chuck, rump, thick flank and topside are not included in the groupings in terms of juiciness and flavour-related characteristics.

This implies that the 16 cuts could sufficiently be described by six cuts for the tenderness characteristics and seven cuts in terms of juiciness and flavour-related characteristics, which means a great saving in cost and time. These groups were more clearly defined applying CVA rather than PCA - as the variability in such data is large and CVA is more appropriate for well-defined groups. The usual correlation coefficients could not effectively describe the groupings of cuts that exhibit similar traits.

Although age had a significant linear relationship with the different tenderness parameters studied, it is strongly recommended that animals of the B-age group with four and six teeth of the various fatness classes should also be evaluated. The study should be similar in order to determine or quantify the influence of these maturity groups on the different parameters used for describing the tenderness, juiciness and flavour of beef.

For nutrient analyses, the neck and chuck emerged as the cuts that were the closest in composition to that of the carcass when the physical dissected tissues of subcutaneous fat, meat and bone of both the carcass and cuts respectively, were included. However, when the physical dissected tissues of subcutaneous fat, meat and bone were excluded, the shoulder was the closest in nutrient composition to the raw carcass. The prime rib grouped the closest with the shoulder second to the nutrient composition of the cooked cuts of the carcass. Should the need arise to analyse beef for nutrient content from time to time to monitor the results of this study, these cuts could successfully be used to describe nutrient content, thereby saving time and analytical costs as the whole carcass need not be analysed again. These results would not have emerged had only ANOVA per variate been used to analyse the data. Multivariate analyses, in this case CVA, is essential to be able to interpret such large data sets.

In this study, nutrient content was determined on the meat and subcutaneous fat. Following recent trends in the UK and USA it is recommended that subcutaneous fat of South African beef for the various age and fatness groups be analysed. This will enable the compilers of food composition tables to calculate the nutrient values of meat on a lean meat only basis. This can be done either as bone-in cuts or according to the more recent trends in the industry as without bone.

Annexure A

Score Sheet Used for Sensory Analyses of Meat

NUTRITIONAL CONTENT OF BEEF

SCORE SHEET FOR CUTS

Name:…………………………………………….Session:………………………………………………..
Date:……………………………………………...Time:…………………………………………………..
Any Health Comments:…………………………………………………………………………………

CHARACTERISTICS	SCORE	SAMPLE NUMBERS		
1.AROMA INTENSITY Take a few short sniffs as soon as you remove the foil	8 Extremely intense 7 Very intense 6 Moderately intense 5 Slightly intense 4 Slightly bland 3 Moderately bland 2 Very bland 1 Extremely bland			
2.1 INITIAL IMPRESSION OF JUICINESS It is the amount of fluid excreted on the cut surface when pressed	8 Extremely juicy 7 Very juicy 6 Moderately juicy 5 Slightly juicy 4 Slightly dry 3 Moderately dry 2 Very dry 1 Extremely dry			
2.2 SUSTAINED JUICINESS It is the impression that you form as you start chewing	8 Extremely juicy 7 Very juicy 6 Moderately juicy 5 Slightly juicy 4 Slightly dry 3 Moderately dry 2 Very dry 1 Extremely dry			
3. MUSCLE FIBRE AND OVERALL TENDERNESS Chew sample with a light chew action	8 Extremely tender 7 Very tender 6 Moderately tender 5 Slightly tender 4 Slightly tough 3 Moderately tough 2 Very tough Extremely tough			
4. AMOUNT OF CONNECTIVE TISSUE (RESIDUE) This is the chewiness of the meat	8 None 7 Practically none 6 Traces 5 Slight 4 Moderate 3 Slightly abundant 2 Moderately abundant 1 Abundant			
5. OVERALL FLAVOUR This is a combination of taste while chewing and swallowing	8 Extremely flavourable 7 Very flavourable 6 Moderately flavourable 5 Slightly flavourable 4 Slightly unflavourable 3 Moderately unflavourable 2 Very unflavourable 1 Extremely unflavourable			

GENERAL COMMENTS……………………………………………………………………………………………………
………

Annexure B

Summaries of Analyses of Variance for all Nutrients Determined

TABLE 1

Least Square Mean Values (± Standard Error of Mean) of Physically Determined Subcutaneous Fat Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Average Chemical Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1.Prime rib	87	0,0001	0,0001		0,5816	6,80	0,421	6,50	0,414	6,17	0,415
2.Loin	80	0,0001	0,0001		0,5476	8,92	1,044	8,54	0,928	9,97	0,932
3.Wing rib	90	0,0001	0,0001		0,9727	9,59	0,554	9,48	0,544	9,66	0,547
4.Rump	63	0,0024	0,0003		0,4528	7,17	1,073	7,48	1,054	9,00	1,058
5.Topside	68	0,0009	0,0002		0,7383	8,61	0,558	8,07	0, 548	8,07	0,550
6.Fillet											
7.Silverside	87	0,0001	0,0001		0,0059	5,88^{a}	0,482	5,62^{a}	0,474	8,00^{b}	0,475
8.Thick flank	49	0,0212	0,0069		0,4795	6,16	0,590	5,19	0,580	5,96	0,582
9.Chuck	82	0,0001	0,0001		0,2674	1,37	0,164	1,47	0,161	1,75	0,162
10.Brisket	73	0,0003	0,0001		0,3624	5,41	0,635	4,20	0,624	5,25	0,627
11.Neck	65	0,0017	0,0002		0,3071	3,81	0,568	3,44	0,558	2,55	0,560
12.Shoulder	84	0,0001	0,8045	0,1487	0,9221	4,56	0,445	4,76	0,439	4,79	0,438
13.Thin flank	72	0,0003	0,0001		0,6196	23,09	1,542	22,05	1,514	20,91	1,521
14.Fore shin	70	0,0007	0,0001		0,0412	0,89^{a}	0,210	0,98^{a}	0,206	1,66^{b}	0,207
15.Hind shin	37	0,0829	0,0201		0,7703	2,07	0,521	1,63	0,512	2,10	0,514
16.Carcass*	74	0,0001	0,0001		0,3251	7,18	0,398	6,41	0,354	6,97	0,355

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 2

Least Square Mean Values (± Standard Error of Mean) of Physically Determined Meat (Excluding Subcutaneous Fat) Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1.Prime rib	39	0,1466	0,0961	0,0936	0,1860	75,23	1,015	76,57	1,002	73,80	0,999
2.Loin	52	0,0210	0,0080		0,1388	71,75	1,491	72,59	1,325	68,73	1,331
3.Wing rib	43	0,0453	0,0660		0,0776	71,53	1,086	73,72	1,067	70,01	1,071
4.Rump	66	0,0014	0,0014		0,0058	75,28^{a}	0,870	74,97^{a}	0,854	71,01^{b}	0,858
5.Topside	47	0,0264	0,0058		0,5399	84,40	0,580	84,91	0,570	84,00	0,572
6.Fillet	0		0,0001	0,0001	0,0001	100,00	0,000	100,00	0,000	100,00	0,000
7.Silverside	86	0,0001	0,0001		0,0076	94,09^{a}	0,488	94,31^{a}	0,479	92,00^{b}	0,481
8.Thick flank	31	0,1443	0,0798		0,5348	90,65	0,608	91,40	0,597	92,00	0,600
9.Chuck	19	0,2032			0,2032	83,14	0,638	83,00	0,638	81,60	0,638
10.Brisket	58	0,0166	0,0317	0,0344	0,0239	76,31^{ab}	0,676	77,21^{a}	0,668	74,29^{b}	0,666
11.Neck	27	0,0936			0,0936	82,17	1,246	81,34	1,246	78,23	1,246
12.Shoulder	80	0,0002	0,2822	0,0455	0,0757	87,07	0,368	86,76	0,363	85,82	0,632
13.Thin flank	69	0,0008	0,0001		0,9171	73,32	1,477	74,18	1,451	73,83	1,457
14.Fore shin	40	0,0642	0,0129		0,3054	44,64	0,747	45,56	0,734	46,35	0,737
15.Hind shin	29	0,3201	0,0896	0,1313	0,7113	33,45	0,970	34,16	0,958	34,59	0,955
16.Carcass*	73	0,0001	0,0068	0,1413	0,0001	86,62^{a}	0,253	86,46^{a}	0,225	85,06^{b}	0,223

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

^{abc} Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 3

Least Square Mean Values (± Standard Error of Mean) of Physically Determined Bone Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g Edible Portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1.Prime rib	76	0,0006	0,0137	0,0569	0,0422	$17,98^{ab}$	0,799	$16,92^{a}$	0,790	$20,04^{b}$	0,787
2.Loin	46	0,0415	0,0316		0,2158	19,34	1,094	18,86	0,972	21,30	0,976
3.Wing rib	66	0,0013	0,0007		0,0469	$18,98^{ab}$	0,927	$16,80^{a}$	0,911	$20,33^{b}$	0,915
4.Rump	58	0,0060	0,0210		0,0283	$17,55^{a}$	0,662	$17,55^{a}$	0,650	$20,00^{b}$	0,653
5.Topside	78	0,0003	0,0032	0,0110	0,0180	$6,94^{a}$	0,219	$7,11^{a}$	0,216	$7,90^{b}$	0,215
6.Fillet						0,00	0,000	0,00	0,000	0,00	0,000
7.Silverside	8	0,5368			0,5368	0,04	0,041	0,07	0,041	0,00	0,041
8.Thick flank	53	0,0131	0,0129		0,0367	$3,19^{ab}$	0,253	$3,42^{a}$	0,249	$2,44^{b}$	0,250
9.Chuck	51	0,0157	0,0050		0,4311	15,65	0,623	15,47	0,612	16,55	0,614
10.Brisket	79	0,0002	0,0192	0,1009	0,0769	18,30	0,682	18,54	0,674	20,49	0,672
11.Neck	63	0,0025	0,0273		0,0094	$14,05^{a}$	1,053	$15,22^{a}$	1,035	$19,21^{b}$	1,039
12.Shoulder	78	0,0001	0,0002		0,0060	$8,38^{a}$	0,206	$8,46^{a}$	0,203	$9,39^{b}$	0,203
13.Thin flank	50	0,0187	0,0965		0,0362	$3,60^{a}$	0,447	$3,77^{a}$	0,439	$5,26^{b}$	0,441
14.Fore shin	72	0,0004	0,0001		0,0260	$54,47^{a}$	0,568	$53,46^{ab}$	0,558	$51,99^{b}$	0,560
15.Hind shin	47	0,0258	0,0034		0,5859	64,60	0,804	64,01	0,790	63,40	0,793
16.Carcass*	74	0,0001	0,0060	0,1312	0,0001	$13,35^{a}$	0,249	$13,54^{a}$	0,221	$14,94^{b}$	0,219

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 4

Least Square Mean Values (± Standard Error of Mean) of Physically Determined Soft Tissue (Meat and Subcutaneous Fat) Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
1.Prime rib	76	0,0006	0,0137	0,0569	0,0422	82,02^{ab}	0,799	83,09^{a}	0,790	79,96^{b}	0,787
2.Loin	46	0,0415	0,0316		0,2158	86,66	1,094	81,14	0,972	78,71	0,976
3.Wing rib	66	0,0013	0,0007		0,0469	81,11^{ab}	0,927	83,20^{a}	0,911	79,67^{b}	0,915
4.Rump	58	0,0060	0,0211		0,0283	82,45^{a}	0,662	82,45^{a}	0,650	80,01^{b}	0,653
5.Topside	78	0,0003	0,0032	0,0110	0,0180	93,06^{a}	0,219	92,89^{a}	0,216	92,10^{b}	0,215
6.Fillet	0		0,0001	0,0001	0,0001	100,00	0,000	100,00	0,000	100,00	0,000
7.Silverside	8	0,5368			0,5368	99,96	0,041	99,94	0,041	100,00	0,041
8.Thick flank	53	0,0131	0,0129		0,0367	96,81^{ab}	0,253	96,59^{a}	0,249	97,56^{b}	0,250
9.Chuck	51	0,0157	0,0050		0,4311	84,35	0,623	84,53	0,612	83,45	0,614
10.Brisket	79	0,0002	0,0192	0,1009	0,0769	81,70	0,682	81,46	0,674	79,51	0,672
11.Neck	63	0,0025	0,0273		0,0094	85,95^{a}	1,053	84,79^{a}	1,035	80,80^{b}	1,039
12.Shoulder	78	0,0001	0,0002		0,0060	91,62^{a}	0,206	91,54^{a}	0,203	90,61^{b}	0,203
13.Thin flank	50	0,0187	0,0965		0,0362	96,41^{a}	0,447	96,23^{a}	0,439	94,74^{b}	0,441
14.Fore shin	72	0,0004	0,0001		0,0260	45,53^{a}	0,568	46,54^{ab}	0,558	48,01^{b}	0,560
15.Hind shin	47	0,0258	0,0034		0,5859	35,40	0,804	35,99	0,790	36,61	0,793
16.Carcass*	44	0,0001	0,0001		0,0024	79,38^{a}	0,439	80,10^{a}	0,390	78,08^{b}	0,392

[1] p-values are of the full model, if not significant ($p \geq 0{,}15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

^{abc} Means in a row with different superscripts differ significantly ($p \leq 0{,}05$)

TABLE 5

Least Square Mean Values (± Standard Error of Mean) of Fat Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	86	0,0001	0,0001		0,2512	21,93	1,424	24,38	1,399	25,38	1,404
2.Loin	87	0,0001	0,0001		0,1294	21,04	1,313	20,19	1,290	23,98	1,295
3.Wing rib	94	0,0001	0,0001		0,1841	23,99	0,967	25,79	0,950	26,63	0,954
4.Rump	92	0,0001	0,0026	0,0814	0,1283	19,68	0,758	19,40	0,749	21,54	0,747
5.Topside	75	0,0008	0,0304	0,1339	0,2026	16,36	0,763	14,36	0,754	15,79	0,751
4.Fillet	45	0,0335	0,0115		0,2539	6,37	0,531	5,82	0,522	7,09	0,524
5.Silverside	77	0,0001	0,0001		0,3563	12,23	0,750	12,52	0,737	13,71	0,740
8.Thick flank	59	0,0049	0,0030		0,2386	13,09	1,330	9,83	1,307	10,70	1,312
9.Chuck	81	0,0001	0,0001		0,1074	16,00	0,997	16,53	0,980	19,02	0,984
10.Brisket	96	0,0001	0,0001		0,0452	32,15^{a}	0,787	32,17^{a}	0,773	29,50^{b}	0,777
11.Neck	91	0,0001	0,0001		0,0070	19,47^{a}	0,694	18,57^{a}	0,681	15,89^{b}	0,684
12.Shoulder	83	0,0001	0,2861	0,0353	0,8053	13,64	0,903	14,27	0,892	14,46	0,889
13.Thin flank	75	0,0002	0,0001		0,6380	32,85	2,111	35,62	2,074	33,63	2,083
14.Fore shin	80	0,0001	0,0001		0,1308	9,24	0,519	7,67	0,510	8,18	0,512
15.Hind shin	54	0,0107	0,0056		0,3101	16,06	1,186	15,01	1,166	13,40	1,170
16.Carcass *	100	0,0001	0,0001		0,2222	19,79	0,112	19,90	0,100	20,07	0,100
COOKED (DRY HEAT)											
1.Prime rib	66	0,0013	0,0001		0,6498	22,38	2,074	24,36	2,032	25,10	2,068
2.Loin	90	0,0001	0,0001		0,7145	21,52	1,022	20,49	1,001	21,50	1,019
3.Wing rib	88	0,0001	0,0001		0,4653	24,51	1,288	22,22	1,261	23,14	1,284
4.Rump	94	0,0001	0,0001		0,0038	23,77^{a}	0,978	25,28^{a}	0,958	19,79^{b}	0,975
5.Topside	78	0,0003	0,0310	0,1441	0,1270	15,31	0,891	14,71	0,872	12,63	0,888
6.Fillet	40	0,0638	0,0404		0,0697	7,78	0,721	9,35	0,707	10,41	0,719
COOKED (MOIST HEAT)											
7.Silverside	92	0,0001	0,0001		0,0172	12,85^{a}	0,513	12,52^{a}	0,503	14,76^{b}	0,512
8.Thick flank	27	0,2070	0,0419		0,9746	10,12	0,852	10,34	0,834	10,38	0,850
9.Chuck	88	0,0001	0,0001		0,6568	21,71	1,121	20,25	1,098	20,78	1,118
10.Brisket	93	0,0001	0,0001		0,3279	33,01	1,022	32,55	1,001	34,68	1,019
11.Neck	82	0,0001	0,0001		0,9861	22,35	1,398	22,60	1,370	22,30	1,395
12.Shoulder	92	0,0001	0,0001		0,5631	17,33	0,611	16,70	0,599	16,39	0,609
13.Thin flank	81	0,0001	0,0001		0,3730	34,36	1,958	37,52	1,918	38,19	1,953
14.Fore shin	71	0,0004	0,0001		0,2559	8,68	0,692	7,57	0,678	9,20	0,691
15.Hind shin	83	0,0001	0,0001		0,0047	15,52^{a}	0,661	11,99^{b}	0,647	12,62^{b}	0,659
16.Carcass *	10	0,5167			0,5167	24,07	2,815	21,14	2,570	19,63	2,570

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 6

Least Square Mean Values (± Standard Error of Mean) of Protein for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	83	0,0001	0,0001		0,0211	18,99^{a}	0,407	17,59^{b}	0,400	17,22^{b}	0,407
2.Loin	36	0,0949	0,0319		0,3127	19,06	0,644	19,31	0,632	17,97	0,644
3.Wing rib	59	0,0048	0,0015		0,4103	17,15	0,787	18,62	0,774	17,54	0,787
4.Rump	18	0,2363			0,2363	16,90	0,798	18,66	0,798	18,63	0,798
5.Topside	1	0,9015			0,9015	19,28	0,634	19,46	0,634	19,05	0,634
4.Fillet	8	0,5392			0,5392	21,16	0,698	21,02	0,698	20,12	0,698
5.Silverside	68	0,0009	0,0013		0,0507	19,22	0,382	20,67	0,375	20,16	0,382
8.Thick flank	17	0,2582			0,2582	17,87	1,298	20,35	1,298	20,80	1,298
9.Chuck	45	0,0788	0,0500	0,0799	0,1070	17,93	0,851	18,84	0,841	16,15	0,851
10.Brisket	78	0,0001	0,0001		0,0165	14,26^{a}	0,541	15,46^{ab}	0,532	16,83^{b}	0,541
11.Neck	46	0,0316	0,0195		0,3020	17,98	0,632	18,28	0,621	19,35	0,632
12.Shoulder	40	0,0613	0,0202		0,4107	19,56	0,618	20,30	0,607	19,13	0,618
13.Thin flank	1	0,9211			0,9211	17,24	1,694	16,50	1,694	17,41	1,694
14.Fore shin	23	0,1368			0,1368	21,00	0,582	22,75	0,582	22,06	0,582
15.Hind shin	29	0,0751			0,0751	19,03	0,858	20,63	0,858	22,05	0,858
16.Carcass*	85	0,0001	0,0001		0,3678	18,16	0,249	18,65	0,221	18,44	0,222
COOKED (DRY HEAT)											
1.Prime rib	67	0,0012	0,0003		0,4368	26,46	0,667	25,70	0,654	26,92	0,665
2.Loin	78	0,0003	0,0166	0,0937	0,4331	28,56	0,675	29,82	0,661	29,18	0,673
3.Wing rib	75	0,0002	0,0002		0,0548	24,83	0,657	25,66	0,644	27,32	0,655
4.Rump	86	0,00001	0,0001		0,0056	27,11^{ab}	0,887	24,50^{a}	0,869	29,34^{b}	0,884
5.Topside	38	0,0746	0,0770		0,2981	29,02	0,751	30,15	0,736	30,75	0,749
6.Fillet	31	0,0620			0,0620	30,50	0,532	28,64	0,532	30,07	0,532
COOKED (MOIST HEAT)											
7.Silverside	41	0,0533	0,0172		0,5531	28,89	0,482	28,48	0,472	29,23	0,480
8.Thick flank	2	0,8424			0,8424	29,95	0,607	30,33	0,607	30,43	0,607
9.Chuck	76	0,0001	0,0001		0,1503	26,13	0,670	27,42	0,656	28,11	0,668
10.Brisket	88	0,0001	0,0515	0,0035	0,7019	21,07^{a}	0,486	20,79^{ab}	0,476	21,37^{b}	0,485
11.Neck	78	0,0001	0,0001		0,0782	24,57	0,760	25,91	0,745	27,28	0,758
12.Shoulder	73	0,0003	0,0001		0,2477	28,24	0,501	28,76	0,490	29,50	0,499
13.Thin flank	58	0,0060	0,0016		0,2293	21,56	1,063	19,12	1,041	21,28	1,060
14.Fore shin	25	0,2489	0,0881		0,7893	29,68	0,895	30,55	0,877	30,22	0,892
15.Hind shin	48	0,0247	0,0467		0,1298	28,01	0,626	29,61	0,614	29,78	0,625
16.Carcass*	96	0,0001	0,0009	0,0595	0,0115	26,16^{a}	0,259	26,27^{a}	0,229	27,29^{b}	0,234

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 7

Least Square Mean Values (± Standard Error of Mean) of Moisture Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	80	0,0001	0,0001		0,6110	58,94	1,286	57,94	1,263	57,10	1,268
2.Loin	76	0,0001	0,0001		0,4695	59,13	1,517	59,94	1,491	57,34	1,497
3.Wing rib	81	0,0001	0,0001		0,3091	58,08	1,300	55,28	1,278	55,84	1,283
4.Rump	78	0,0001	0,0001		0,1482	62,21	1,008	61,18	0,991	59,27	0,995
5.Topside	73	0,0003	0,0001		0,4213	63,97	0,708	65,23	0,695	65,08	0,698
4.Fillet	51	0,0168	0,0054		0,5025	71,37	0,679	72,50	0,667	71,74	0,669
5.Silverside	76	0,0001	0,0001		0,0148	$67,87^{a}$	0,643	$66,57^{ab}$	0,632	$64,78^{b}$	0,635
8.Thick flank	76	0,0001	0,0001		0,0697	67,63	0,538	69,10	0,529	67,32	0,531
9.Chuck	82	0,0001	0,0001		0,5334	64,28	0,807	64,29	0,793	63,16	0,796
10.Brisket	91	0,0001	0,0001		0,4302	52,53	0,798	51,42	0,784	52,82	0,787
11.Neck	90	0,0001	0,0001		0,1738	61,99	0,575	62,58	0,565	63,60	0,568
12.Shoulder	65	0,0054	0,4416	0,1433	0,8435	65,97	0,903	65,26	0,892	65,82	0,889
13.Thin flank	88	0,0001	0,0001		0,8849	48,60	1,105	47,98	1,085	48,68	1,090
14.Fore shin	75	0,0002	0,0001		0,7682	69,28	0,426	69,53	0,419	69,10	0,421
15.Hind shin	50	0,0178	0,0026		0,9756	64,11	0,901	64,23	0,885	63,95	0,889
16.Carcass*	99	0,0001	0,0001		0,3839	61,13	0,248	60,95	0,220	60,65	0,221
COOKED (DRY HEAT)											
1.Prime rib	62	0,0030	0,0003		0,4548	50,29	1,609	48,41	1,577	47,33	1,605
2.Loin	71	0,0005	0,0001		0,9977	48,68	1,309	48,61	1,282	48,55	1,305
3.Wing rib	88	0,0001	0,0001		0,2146	49,48	0,956	50,80	0,937	48,33	0,954
4.Rump	79	0,0001	0,0001		0,4771	47,76	0,840	48,93	0,823	49,16	0,838
5.Topside	75	0,0002	0,0001		0,2392	54,29	0,714	54,02	0,699	55,70	0,712
6.Fillet	40	0,0615	0,0309		0,1015	60,59	0,692	60,65	0,678	58,64	0,690
COOKED (MOIST HEAT)											
7.Silverside	84	0,0001	0,0001		0,0714	57,18	0,566	57,43	0,554	55,56	0,564
8.Thick flank	37	0,0812	0,0150		0,5999	59,02	0,679	58,04	0,665	58,40	0,677
9.Chuck	81	0,0001	0,1340	0,6832	0,8354	51,14	0,997	51,11	0,977	50,39	0,994
10.Brisket	90	0,0001	0,0001		0,3069	44,38	0,857	45,16	0,840	43,25	0,855
11.Neck	72	0,0004	0,0001		0,6020	51,45	1,163	50,57	1,140	49,73	1,160
12.Shoulder	92	0,0001	0,0001		0,6568	53,25	0,423	53,74	0,414	53,29	0,422
13.Thin flank	87	0,0001	0,0001		0,2155	42,96	1,163	42,05	1,140	39,95	1,160
14.Fore shin	56	0,0237	0,2528	0,0998	0,3490	61,10	0,641	61,43	0,628	60,12	0,640
15.Hind shin	55	0,0089	0,0068		0,1556	55,78	0,816	58,14	0,799	56,92	0,813
16.Carcass*	98	0,0001	0,0304	0,1057	0,0486	$51,27^{a}$	0,287	$51,15^{a}$	0,253	$50,30^{b}$	0,258

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

abc Means in a row with different superscripts differ significantly($p \leq 0,05$)

TABLE 8

Least Square Mean Values (± Standard Error of Mean) of Phosphorus Content for Beef Cuts Obtained from Three Age Groups (n = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	91	0,0001	0,0001		0,0843	155	2,269	149	2,229	147	2,238
2.Loin	61	0,0109	0,1981	0,0652	0,1805	168	6,216	156	6,141	151	6,123
3.Wing rib	77	0,0001	0,0001		0,0979	158	5,439	158	5,343	142	5,365
4.Rump	69	0,0007	0,0001		0,1354	177	3,865	175	3,797	166	3,812
5.Topside	7	0,5781			0,5781	180	5,825	189	5,825	183	5,825
4.Fillet	9	0,4893			0,4893	207	7,025	197	7,025	195	7,025
5.Silverside	50	0,0174	0,0096		0,2582	179	4,789	190	4,705	181	4,724
8.Thick flank	9	0,5051			0,5051	161	12,585	182	12,585	175	12,585
9.Chuck	45	0,0364	0,0057		0,9581	164	2,107	164	2,070	162	2,079
10.Brisket	22	0,1540			0,1540	129	10,309	157	10,309	10,309	10,309
11.Neck	55	0,0092	0,0039		0,3995	152	4,540	161	4,461	158	4,479
12.Shoulder	44	0,0372	0,0276		0,2220	163	5,047	175	4,958	165	4,978
13.Thin flank	5	0,6608			0,6608	147	16,381	127	16,381	130	16,381
14.Fore shin	17	0,2458			0,2458	155	4,710	166	4,710	165	4,710
15.Hind shin	36	0,0359			0,0359	137^{a}	5,139	157^{b}	5,139	152^{ab}	5,139
16.Carcass*	78	0,0001	0,0001		0,0901	160	2,932	167	2,605	158	2,617
COOKED (DRY HEAT)											
1.Prime rib	53	0,0126	0,0060		0,2163	167	6,571	183	6,437	170	6,553
2.Loin	64	0,0066	0,0530	0,1292	0,0329	202^{a}	7,765	229^{b}	7,606	200^{a}	7,744
3.Wing rib	54	0,0100	0,0340		0,0309	163^{a}	5,796	187^{b}	5,678	172^{ab}	5,780
4.Rump	54	0,0105	0,0312		0,0325	174^{a}	6,283	200^{b}	6,154	182^{ab}	6,265
5.Topside	28	0,0095			0,0995	195	8,359	220	8,359	196	9,157
6.Fillet	6	0,6658			0,6658	223	8,517	215	9,330	212	8,517
COOKED (MOIST HEAT)											
7.Silverside	9	0,4870			0,4870	185	12,107	194	12,107	206	12,107
8.Thick flank	18	0,2295			0,2295	193	6,937	201	6,937	183	6,937
9.Chuck	56	0,0069	0,0101		0,0460	163^{a}	4,947	181^{b}	4,846	166^{ab}	4,933
10.Brisket	77	0,0001	0,0001		0,0074	131^{a}	4,012	148^{b}	3,930	128^{a}	4,001
11.Neck	74	0,0002	0,0007		0,0163	154^{a}	3,496	170^{b}	3,424	168^{b}	3,486
12.Shoulder	29	0,0747			0,0747	171	4,938	188	4,938	178	4,938
13.Thin flank	49	0,0210	0,0065		0,1347	124	6,743	131	6,605	111	6,724
14.Fore shin	18	0,2182			0,2182	168	7,056	177	7,056	159	7,056
15.Hind shin	50	0,0057			0,0057	153^{a}	3,699	173^{b}	3,699	163^{ab}	3,699
16.Carcass*	64	0,0035	0,0044		0,0331	165	4,861	181	4,301	165	4,390

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly (p ≤ 0,05)

TABLE 9
Least Square Mean Values (± Standard Error of Mean) of Calcium Content for Beef Cuts Obtained from Three Age Groups ($n = 18$) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	49	0,0520	0,0833	0,0366	0,5941	18,7	1,317	20,0	1,301	20,6	1,297
2.Loin	34	0,0470			0,0470	22,9^{a}	1,779	22,3^{a}	1,779	16,7^{b}	1,779
3.Wing rib	2	0,8551			0,8551	18,6	2,129	19,1	2,129	20,2	2,129
4.Rump	3	0,8257			0,8257	13,8	1,411	13,7	1,411	12,7	1,411
5.Topside	3	0,7882			0,7882	11,3	1,320	11,1	1,320	10,1	1,320
4.Fillet	13	0,3684			0,3684	9,0	1,549	10,1	1,549	7,0	1,549
5.Silverside	27	0,2083	0,1195		0,2583	8,4	1,395	11,6	1,370	9,0	1,376
8.Thick flank	8	0,5178			0,5178	9,9	1,758	11,7	1,758	8,8	1,758
9.Chuck	57	0,0202	0,0029	0,0018	0,9082	16,1	1,486	17,0	1,468	16,7	1,464
10.Brisket	37	0,0867	0,0335		0,2563	15,4	1,429	18,4	1,404	15,5	1,409
11.Neck	13	0,3664			0,3664	16,8	1,572	15,9	1,572	19,1	1,572
12.Shoulder	67	0,0039	0,1044	0,0339	0,0238	10,6^{a}	1,314	12,3^{a}	1,298	16,3^{b}	1,294
13.Thin flank	4	0,7555			0,7555	14,5	1,933	12,9	1,933	12,5	1,933
14.Fore shin	9	0,4852			0,4852	12,4	2,382	14,5	2,382	10,4	2,382
15.Hind shin	26	0,2235	0,0968		0,2825	11,2	1,988	13,0	1,953	15,8	1,961
16.Carcass*	27	0,2306	0,0484		0,8331	13,7	1,324	14,8	1,176	14,3	1,182
COOKED (DRY HEAT)											
1.Prime rib	5	0,6790			0,6790	21,7	3,115	18,5	3,115	18,2	3,115
2.Loin	9	0,4863			0,4863	53,2	6,966	59,0	6,966	65,3	6,966
3.Wing rib	44	0,0379	0,0351		0,0702	18,9	1,722	24,9	1,686	21,0	1,717
4.Rump	37	0,0306			0,0306	9,7^{a}	0,887	13,4^{b}	0,887	12,0^{ab}	0,887
5.Topside	16	0,3033			0,3033	13,0	1,382	15,3	1,382	12,2	1,514
6.Fillet	6	0,6477			0,6477	9,9	1,571	8,6	1,720	7,8	1,571
COOKED (MOIST HEAT)											
7.Silverside	38	0,0913	0,1035		0,0695	5,5	0,544	7,2	0,534	7,3	0,595
8.Thick flank	15	0,2931			0,2931	6,8	0,607	8,2	0,607	7,5	0,607
9.Chuck	22	0,1627			0,1627	13,9	1,747	18,6	1,747	17,7	1,747
10.Brisket	20	0,1970			0,1970	10,9	1,184	13,9	1,184	13,2	1,184
11.Neck	19	0,2106			0,2106	13,0	1,269	14,9	1,269	16,4	1,269
12.Shoulder	24	0,1322			0,1322	8,6	0,854	11,2	0,854	9,5	0,854
13.Thin flank	50	0,0075			0,0075	6,0^{a}	0,903	10,4^{b}	0,824	9,5^{b}	0,824
14.Fore shin	11	0,4088			0,4088	9,2	0,812	10,0	0,812	8,5	0,812
15.Hind shin	16	0,2784			0,2784	10,8	1,043	11,7	1,043	9,2	1,043
16.Carcass*	36	0,0440			0,0440	12,3	0,754	15,1	0,688	14,5	0,688

[1] p-values are of the full model, if not significant ($p \geq 0{,}15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0{,}05$)

TABLE 10

Least Square Mean Values (± Standard Error of Mean) of Magnesium Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEN	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	48	0,0593	0,0766	0,0393	0,3603	17,6	1,101	16,6	1,088	18,9	1,084
2.Loin	3	0,7799			0,7799	19,0	1,261	18,4	1,261	19,7	1,261
3.Wing rib	39	0,0674	0,0144		0,9435	17,7	1,275	18,2	1,253	18,3	1,258
4.Rump	16	0,4697	0,1473		0,9580	19,7	1,304	20,1	1,281	19,6	1,287
5.Topside	12	0,3884			0,3884	20,3	1,229	22,8	1,229	21,5	1,229
4.Fillet	5	0,7054			0,7054	22,4	1,523	21,3	1,523	23,1	1,523
5.Silverside	9	0,5010			0,5010	19,2	1,426	21,2	1,426	21,3	1,426
8.Thick flank	5	0,678			0,6780	18,3	1,895	20,2	1,895	20,6	1,895
9.Chuck	20	0,1970			0,1970	18,4	4,514	18,8	4,514	29,1	4,514
10.Brisket	26	0,2219	0,0936		0,6595	15,5	1,612	17,5	1,584	16,3	1,590
11.Neck	52	0,0373	0,0836	0,0403	0,4869	17,8	0,797	18,3	0,787	19,1	0,785
12.Shoulder	47	0,0273	0,0150		0,2444	18,9	0,836	20,7	0,821	18,9	0,824
13.Thin flank	3	0,7724			0,7724	16,3	2,163	14,3	2,163	16,2	2,163
14.Fore shin	8	0,5254			0,5254	18,3	1,415	17,8	1,415	20,0	1,415
15.Hind shin	41	0,0538	0,0410		0,2578	16,7	0,801	18,6	0,787	17,3	0,790
16.Carcass*	60	0,0061	0,0053		0,2019	18,2	0,692	19,0	0,615	20,0	0,618
COOKED (DRY HEAT)											
1.Prime rib	18	0,4064	0,1071		0,8948	23,7	1,168	22,9	1,144	23,2	1,164
2.Loin	66	0,0015	0,0008		0,0100	29,2^a	1,055	29,9^a	1,034	24,9^b	1,052
3.Wing rib	53	0,0351	0,0422	0,0820	0,2572	24,6	1,290	23,3	1,264	26,4	1,286
4.Rump	18	0,4261	0,1306		0,9732	24,4	1,014	24,7	0,993	24,6	1,011
5.Topside	8	0,5522			0,5522	26,4	0,976	27,6	0,976	26,2	1,069
6.Fillet	18	0,2435			0,2435	29,0	0,739	27,2	0,809	28,7	0,739
COOKED (MOIST HEAT)											
7.Silverside	9	0,4981			0,4981	26,3	1,392	24,0	1,392	25,5	1,392
8.Thick flank	9	0,4918			0,4918	25,2	0,756	23,9	0,756	24,4	0,756
9.Chuck	4	0,7645			0,7645	22,9	1,003	22,9	1,003	23,8	1,003
10.Brisket	29	0,1756	0,0732		0,4249	19,6	0,952	18,0	0,932	19,5	0,949
11.Neck	54	0,0112	0,0130		0,1118	22,2	0,908	21,2	0,890	24,0	0,906
12.Shoulder	4	0,7561			0,7561	23,7	0,904	24,5	0,904	24,5	0,904
13.Thin flank	31	0,1460	0,0320		0,6856	16,9	0,955	15,7	0,935	16,3	0,952
14.Fore shin	26	0,1030			0,1030	23,5	0,706	22,0	0,706	24,3	0,706
15.Hind shin	8	0,5275			0,5275	21,2	0,926	21,6	0,926	22,7	0,926
16.Carcass*	30	0,1847	0,0421		0,9172	23,0	0,745	22,6	0,659	22,9	0,673

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 11

Least Square Mean Values (± Standard Error of Mean) of Potassium Content for Beef Cuts Obtained from Three Age Groups (n=18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	56	0,0083	0,0013		0,9775	258	9,463	259	9,297	261	9,335
2.Loin	29	0,1733	0,0335		0,8798	283	3,249	282	13,016	274	13,069
3.Wing rib	38	0,0768	0,0136		0,8060	265	22,384	268	21,990	249	22,080
4.Rump	53	0,0131	0,0017		0,6955	309	7,927	307	7,788	300	7,820
5.Topside	7	0,5798			0,5798	319	13,596	339	13,596	326	13,596
4.Fillet	9	0,4807			0,4807	356	12,508	348	12,508	334	12,508
5.Silverside	26	0,2196	0,1174		0,4797	320	12,543	339	12,322	3,21	12,372
8.Thick flank	9	0,4788			0,4788	277	24,926	321	24,926	278	24,926
9.Chuck	1	0,9624			0,9624	280	15,336	282	15,336	286	15,336
10.Brisket	31	0,0629			0,0629	200	20,206	273	20,206	227	20,206
11.Neck	39	0,0704	0,0481		0,3889	261	11,125	280	10,929	281	10,974
12.Shoulder	40	0,0590	0,0738		0,1668	284	12,790	319	12,565	293	12,616
13.Thin flank	2	0,8913			0,8913	242	33,232	220	33,232	225	33,232
14.Fore shin	46	0,0729	0,0735	0,0704	0,0518	240^{a}	11,170	277^{b}	11,036	278^{b}	11,003
15.Hind shin	46	0,0098			0,0098	225^{a}	9,308	263^{b}	9,308	268^{b}	9,308
16.Carcass*	47	0,0357	0,0231		0,3057	272	10,175	293	9,040	278	9,082
COOKED (DRY HEAT)											
1.Prime rib	55	0,0093	0,0072		0,1685	266	11,522	298	11,287	284	11,49
2.Loin	62	0,0030	0,0014		0,1168	302	10,340	331	10,128	304	10,311
3.Wing rib	65	0,0055	0,3111	0,1157	0,1246	275	10,920	306	10,697	280	10,890
4.Rump	51	0,0165	0,0152		0,1300	272	9,881	302	9,678	283	9,853
5.Topside	20	0,2024			0,2024	303	15,785	346	15,785	321	17,292
6.Fillet	5	0,7123			0,7123	349	6,883	351	7,540	357	6,883
COOKED (MOIST HEAT)											
7.Silverside	14	0,3192			0,3192	291	18,092	308	18,092	331	18,092
8.Thick flank	18	0,2352			0,2352	294	10,793	321	10,793	305	10,793
9.Chuck	42	0,0511	0,0222		0,3418	251	9,886	270	9,683	254	9,858
10.Brisket	89	0,0001	0,0001		0,0361	213^{ab}	4,821	225^{a}	4,722	206^{b}	4,807
11.Neck	27	0,0990			0,0990	233	25,772	264	25,772	317	25,772
12.Shoulder	23	0,1435			0,1435	264	28,632	282	28,632	345	28,632
13.Thin flank	66	0,0015	0,0002		0,3176	211	9,623	211	9,426	193	9,596
14.Fore shin	13	0,3491			0,3491	265	7,443	281	7,443	276	7,443
15.Hind shin	17	0,2530			0,2530	240	26,113	266	26,113	303	26,113
16.Carcass*	48	0,0325	0,0228		0,3695	260	10,775	280	9,535	277	9,732

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 12

Least Square Mean Values (± Standard Error of Mean) of Sodium Content for Beef Cuts Obtained from Three Age Groups (*n*=18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^{2} %	p-Value	X p-Value	X^{2} p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	2	0,8810			0,8810	81	4,431	82	4,431	84	4,431
2.Loin	38	0,1596	0,1356	0,1057	0,2249	85	4,480	90	4,426	78	4,413
3.Wing rib	18	0,2286			0,2286	79	5,548	93	5,548	86	5,548
4.Rump	45	0,0786	0,0675	0,0712	0,1112	76	3,593	88	3,550	80	3,539
5.Topside	28	0,3433	0,1335	0,1361	0,4482	77	3,760	84	3,715	81	3,704
4.Fillet	1	0,9611			0,9611	84	3,769	84	3,769	85	3,769
5.Silverside	50	0,0054			0,0054	73^{a}	3,571	93^{b}	3,571	85^{b}	3,571
8.Thick flank	19	0,2010			0,2010	86	7,319	98	7,319	105	7,319
9.Chuck	10	0,4413			0,4413	90	5,021	99	5,021	95	5,021
10.Brisket	24	0,1311			0,1311	95	7,384	117	7,384	111	7,384
11.Neck	15	0,2952			0,2952	99	5,745	112	5,745	105	5,745
12.Shoulder	8	0,5400			0,5400	92	4,486	98	4,486	91	4,486
13.Thin flank	1	0,9084			0,9084	102	8,309	105	8,309	107	8,309
14.Fore shin	6	0,6193			0,6193	119	6,144	127	6,144	126	6,144
15.Hind shin	13	0,3664			0,3644	115	6,271	128	6,271	122	6,271
16.Carcass*	21	0,1923			0,1923	88	4,710	100	4,300	95	4,300
COOKED (DRY HEAT)											
1.Prime rib	57	0,0065	0,0399		0,0240	83^{a}	3,182	97^{b}	3,117	93^{ab}	3,174
2.Loin	40	0,0209			0,0209	79^{a}	4,579	99^{b}	4,579	90^{ab}	4,579
3.Wing rib	62	0,0007			0,0007	79^{a}	3,259	101^{b}	3,259	96^{b}	3,259
4.Rump	47	0,0088			0,0088	66^{a}	3,897	86^{b}	3,897	80^{b}	3,897
5.Topside	59	0,0216	0,1139	0,1183	0,0095	76^{a}	3,556	94^{a}	3,443	90^{b}	3,948
6.Fillet	47	0,0113			0,0113	78^{a}	3,318	92^{b}	3,634	93^{b}	3,318
COOKED (MOIST HEAT)											
7.Silverside	23	0,1358			0,1358	69	4,919	82	4,919	83	4,919
8.Thick flank	48	0,0076			0,0076	74^{a}	5,444	102^{b}	5,444	92^{b}	5,444
9.Chuck	42	0,0166			0,0166	72^{a}	3,412	87^{b}	3,412	84^{b}	3,412
10.Brisket	61	0,0035	0,0274		0,0216	81^{a}	4,155	96^{b}	4,070	99^{b}	4,144
11.Neck	12	0,3835			0,3835	90	5,926	102	5,926	99	5,926
12.Shoulder	17	0,2541			0,2541	81	9,035	95	9,035	103	9,035
13.Thin flank	42	0,0495	0,0734		0,1773	83	5,193	97	5,087	95	5,179
14.Fore shin	53	0,0322	0,0552	0,0475	0,0345	105^{a}	3,432	118^{b}	3,362	117^{b}	3,423
15.Hind shin	52	0,0356	0,0648	0,0988	0,0602	106	4,483	122	4,391	114	4,471
16.Carcass*	40	0,0279			0,0279	79^{a}	3,974	95^{b}	3,628	93^{b}	3,628

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^{2} and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 13

Least Square Mean Values ((± Standard Error of Mean) of Copper Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	29	0,1716	0,0583		0,2681	0,208	0,039	0,142	0,039	0,116	0,039
2.Loin	31	0,0609			0,0609	0,270	0,042	0,156	0,042	0,121	0,042
3.Wing rib	15	0,2851			0,2851	0,226	0,043	0,205	0,043	0,131	0,043
4.Rump	32	0,2539	0,1402	0,1095	0,2026	0,233	0,035	0,143	0,035	0,159	0,035
5.Topside	20	0,1927			0,1927	0,222	0,033	0,139	0,033	0,152	0,033
4.Fillet	7	0,6037			0,6037	0,204	0,033	0,157	0,033	0,184	0,033
5.Silverside	5	0,6651			0,6651	0,171	0,029	0,161	0,029	0,135	0,029
8.Thick flank	15	0,2923			0,2933	0,132	0,086	0,328	0,086	0,198	0,086
9.Chuck	8	0,5329			0,5329	0,184	0,059	0,221	0,059	0,126	0,059
10.Brisket	10	0,4656			0,4656	0,233	0,049	0,198	0,049	0,147	0,049
11.Neck	25	0,4038	0,1677	0,1204	0,7355	0,161	0,030	0,141	0,030	0,128	0,030
12.Shoulder	0,2	0,9887			0,9887	0,126	0,025	0,127	0,025	0,131	0,025
13.Thin flank	16	0,2698			0,2698	0,290	0,058	0,198	0,058	0,155	0,058
14.Fore shin	21	0,5159	0,1439	0,1301	0,5595	0,170	0,031	0,135	0,030	0,179	0,030
15.Hind shin	1	0,9167			0,9167	0,140	0,032	0,139	0,032	0,123	0,032
16.Carcass*	45	0,1033	0,1135	0,0708	0,0919	0,229	0,027	0,165	0,024	0,141	0,024
COOKED (DRY HEAT)											
1.Prime rib	8	0,5475			0,5475	0,137	0,025	0,171	0,025	0,137	0,025
2.Loin	18	0,2205			0,2205	0,133	0,037	0,207	0,037	0,118	0,037
3.Wing rib	12	0,3935			0,3935	0,110	0,009	0,115	0,009	0,127	0,009
4.Rump	22	0,3184	0,1376		0,4647	0,143	0,036	0,207	0,035	0,166	0,036
5.Topside	26	0,2506	0,0984		0,3718	0,130	0,044	0,217	0,042	0,192	0,048
6.Fillet	11	0,4569			0,4569	0,189	0,031	0,245	0,034	0,229	0,031
COOKED (MOIST HEAT)											
7.Silverside	32	0,1391	0,0606		0,2348	0,137	0,048	0,258	0,047	0,210	0,048
8.Thick flank	43	0,1018	0,0671	0,1335	0,4854	0,140	0,024	0,171	0,024	0,181	0,024
9.Chuck	48	0,0568	0,0646	0,1079	0,0568	0,090	0,012	0,131	0,012	0,127	0,012
10.Brisket	40	0,0226			0,0226	0,084^{a}	0,010	0,114^{ab}	0,010	0,129^{b}	0,010
11.Neck	9	0,5109			0,5109	0,194	0,042	0,137	0,042	0,130	0,042
12.Shoulder	50	0,0178	0,1051		0,0116	0,198^{a}	0,013	0,163^{a}	0,013	0,128^{ab}	0,013
13.Thin flank	1	0,9282			0,9282	0,109	0,019	0,100	0,019	0,109	0,019
14.Fore shin	24	0,4304	0,0770	0,0788	0,8312	0,161	0,018	0,146	0,017	0,156	0,018
15.Hind shin	40	0,0580	0,1354		0,0453	0,115^{a}	0,016	0,179^{b}	0,016	0,140^{b}	0,016
16.Carcass*	37	0,1015	0,0445		0,1853	0,121	0,017	0,164	0,015	0,145	0,015

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 14

Least Square Mean Values (± Standard Error of Mean) of Zinc Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	59	0,0053	0,0013		0,4228	3,20	0,107	3,13	0,105	3,33	0,106
2.Loin	2	0,8433			0,8433	2,87	0,153	2,81	0,153	2,74	0,153
3.Wing rib	49	0,0204	0,0060		0,6386	2,87	0,209	3,15	0,206	3,04	0,206
4.Rump	17	0,4413	0,1147		0,9677	3,02	0,158	2,97	0,155	2,97	0,156
5.Topside	8	0,5406			0,5406	2,93	0,129	3,12	0,129	3,09	0,129
4.Fillet	24	0,1307			0,1307	3,16	0,167	2,88	0,167	2,65	0,167
5.Silverside	21	0,3332	0,1451		0,7461	2,78	0,147	2,94	0,144	2,87	0,145
8.Thick flank	8	0,5185			0,5185	3,38	0,295	3,86	0,295	3,59	0,295
9.Chuck	8	0,5330			0,5330	4,64	0,234	4,84	0,234	5,02	0,234
10.Brisket	25	0,1164			0,1164	2,68	0,313	3,66	0,313	3,21	0,313
11.Neck	63	0,0026	0,0075		0,0342	4,14^{a}	0,130	4,32^{ab}	0,128	4,67^{b}	0,128
12.Shoulder	51	0,0173	0,0094		0,1927	3,63	0,157	3,97	0,155	3,58	0,155
13.Thin flank	9	0,5113			0,5113	2,95	0,343	2,87	0,343	3,41	0,343
14.Fore shin	24	0,1277			0,1277	4,35	0,223	4,94	0,223	4,96	0,223
15.Hind shin	19	0,2030			0,2030	3,21	0,198	3,50	0,198	3,73	0,198
16.Carcass*	58	0,0081	0,0121		0,1337	3,28	0,110	3,59	0,098	3,53	0,098
COOKED (DRY HEAT)											
1.Prime rib	37	0,0809	0,0986		0,2428	4,42	0,352	5,20	0,344	5,17	0,351
2.Loin	44	0,0123			0,0123	3,79^{a}	0,175	4,60^{b}	0,175	3,95^{a}	0,175
3.Wing rib	41	0,0573	0,0846		0,1647	3,83	0,236	4,49	0,231	4,28	0,235
4.Rump	35	0,0986	0,1249		0,2236	3,93	0,229	4,51	0,225	4,34	0,229
5.Topside	17	0,2693			0,2693	4,22	0,202	4,71	0,202	4,46	0,221
6.Fillet	9	0,5229			0,5229	4,21	0,151	4,07	0,166	3,96	0,151
COOKED (MOIST HEAT)											
7.Silverside	10	0,4639			0,4639	3,72	0,234	4,13	0,234	4,01	0,234
8.Thick flank	7	0,5630			0,5630	5,50	0,161	5,65	0,161	5,41	0,161
9.Chuck	41	0,0558	0,0227		0,5736	6,58	0,466	7,23	0,456	7,15	0,465
10.Brisket	59	0,0053	0,0073		0,1190	3,53	0,198	4,04	0,194	4,11	0,197
11.Neck	58	0,0059	0,0130		0,0840	5,01	0,459	6,01	0,450	6,70	0,451
12.Shoulder	54	0,0103	0,0259		0,0630	5,26	0,175	5,89	0,172	5,71	0,175
13.Thin flank	53	0,0125	0,0038		0,5326	3,23	0,198	3,54	0,194	3,41	0,197
14.Fore shin	26	0,1009			0,1009	6,35	0,253	6,84	0,253	7,17	0,253
15.Hind shin	44	0,0124			0,0124	4,51^{a}	0,171	5,24^{b}	0,171	5,22^{b}	0,171
16.Carcass*	56	0,0112	0,0161		0,1394	4,42	0,217	5,03	0,192	4,90	0,196

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

abc Means in a row with different superscripts differ significantly (p ≤ 0,05)

TABLE 15

Least Square Mean Values (± Standard Error of Mean) of Manganese Values for Beef Cuts Obtained from Three Age Groups (n = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	18	0,4243	0,1264		0,6690	0,015	0,002	0,013	0,002	0,012	0,002
2.Loin	6	0,6395			0,6395	0,014	0,002	0,014	0,002	0,011	0,002
3.Wing rib	25	0,1220			0,1220	0,014	0,002	0,018	0,002	0,011	0,002
4.Rump	33	0,2280	0,0877	0,0884	0,3583	0,014	0,002	0,016	0,002	0,013	0,002
5.Topside	29	0,0778			0,0778	0,014	0,002	0,017	0,002	0,011	0,002
4.Fillet	1	0,9614			0,9614	0,014	0,002	0,014	0,002	0,013	0,002
5.Silverside	25	0,1133			0,1133	0,013	0,002	0,017	0,002	0,011	0,002
8.Thick flank	19	0,2062			0,2062	0,012	0,001	0,015	0,001	0,012	0,001
9.Chuck	4	0,7168			0,7168	0,014	0,002	0,015	0,002	0,012	0,002
10.Brisket	19	0,2002			0,2002	0,013	0,002	0,017	0,002	0,014	0,002
11.Neck	27	0,0952			0,0952	0,01	0,002	0,02	0,002	0,01	0,002
12.Shoulder	17	0,2406			0,2406	0,013	0,002	0,014	0,002	0,010	0,002
13.Thin flank	10	0,4698			0,4698	0,015	0,002	0,016	0,002	0,012	0,002
14.Fore shin	6	0,6152			0,6152	0,014	0,002	0,015	0,002	0,013	0,002
15.Hind shin	19	0,2136			0,2136	0,013	0,002	0,019	0,002	0,013	0,002
16.Carcass*	18	0,2443			0,2443	0,014	0,002	0,017	0,002	0,012	0,002
COOKED (DRY HEAT)											
1.Prime rib	12	0,3705			0,3705	0,014	0,003	0,015	0,003	0,020	0,003
2.Loin	31	0,1413	0,0708		0,1936	0,009	0,012	0,041	0,012	0,031	0,012
3.Wing rib	29	0,0759			0,0759	0,009	0,004	0,016	0,004	0,025	0,004
4.Rump	30	0,0690			0,0690	0,014	0,005	0,023	0,005	0,031	0,005
5.Topside	23	0,1664			0,1664	0,015	0,005	0,023	0,005	0,030	0,005
6.Fillet	12	0,4126			0,4126	0,022	0,003	0,026	0,003	0,025	0,003
COOKED (MOIST HEAT)											
7.Silverside	26	0,2275	0,1365		0,2609	0,014	0,007	0,031	0,007	0,022	0,007
8.Thick flank	34	0,1123	0,0769		0,1071	0,015	0,002	0,019	0,002	0,020	0,002
9.Chuck	3	0,7811			0,7811	0,023	0,008	0,016	0,008	0,022	0,008
10.Brisket	11	0,4191			0,4191	0,018	0,006	0,018	0,006	0,027	0,006
11.Neck	9	0,4753			0,4753	0,013	0,004	0,017	0,004	0,019	0,004
12.Shoulder	30	0,1626	0,0676		0,1980	0,016	0,002	0,020	0,002	0,022	0,002
13.Thin flank	27	0,0978			0,0978	0,012	0,005	0,018	0,005	0,027	0,005
14.Fore shin	12	0,3910			0,3910	0,018	0,761	1,337	0,761	0,020	0,761
15.Hind shin	34	0,1133	0,0213		0,4708	0,015	0,003	0,019	0,003	0,020	0,003
16.Carcass*	11	0,4486			0,4486	0,018	0,024	0,057	0,022	0,023	0,022

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly (p ≤ 0,05)

TABLE 16

Least Square Mean Values (± Standard Error of Mean) of Iron Content for Beef Cuts Obtained from Three Age Groups (n = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	54	0,0031			0,0031	$0,87^{a}$	0,173	$1,02^{a}$	0,173	$1,82^{b}$	0,173
2.Loin	67	0,0002			0,0002	$0,84^{a}$	0,147	$0,92^{a}$	0,147	$1,87^{b}$	0,147
3.Wing rib	58	0,0014			0,0014	$0,72^{a}$	0,148	$0,95^{a}$	0,148	$1,64^{b}$	0,148
4.Rump	60	0,0011			0,0011	$0,94^{a}$	0,203	$1,18^{a}$	0,203	$2,22^{b}$	0,203
5.Topside	58	0,0014			0,0014	$0,89^{a}$	0,195	$1,12^{a}$	0,195	$2,08^{b}$	0,195
4.Fillet	49	0,0061			0,0061	$1,20^{a}$	0,238	$1,22^{a}$	0,238	$2,32^{b}$	0,238
5.Silverside	59	0,0012			0,0012	$0,76^{a}$	0,192	$1,03^{a}$	0,192	$1,97^{b}$	0,192
8.Thick flank	30	0,0657			0,0657	1,18	0,240	1,03	0,240	1,85	0,240
9.Chuck	62	0,0101	0,1297	0,1298	0,0046	$0,93^{a}$	0,207	$1,16^{a}$	0,204	$2,06^{b}$	0,204
10.Brisket	53	0,0034			0,0034	$0,77^{a}$	0,174	$1,07^{a}$	0,174	$1,76^{b}$	0,174
11.Neck	49	0,0069			0,0069	$1,03^{a}$	0,233	$1,18^{a}$	0,233	$2,17^{b}$	0,233
12.Shoulder	35	0,0407			0,0407	$0,93^{a}$	0,248	$1,15^{ab}$	0,248	$1,88^{b}$	0,248
13.Thin flank	67	0,0041	0,0522	0,0562	0,0026	$0,66^{a}$	0,157	$0,88^{a}$	0,155	$1,60^{b}$	0,155
14.Fore shin	50	0,0059			0,0059	$0,76^{a}$	0,236	$1,13^{a}$	0,236	$2,01^{b}$	0,236
15.Hind shin	42	0,0165			0,0165	$0,90^{a}$	0,211	$1,08^{a}$	0,211	$1,83^{b}$	0,211
16.Carcass*	52	0,0056			0,0056	0,94	0,208	1,08	0,190	1,94	0,190
COOKED (DRY HEAT)											
1.Prime rib	33	0,0488			0,0488	$1,78^{a}$	0,235	$2,57^{b}$	0,235	$2,56^{b}$	0,235
2.Loin	69	0,0028	0,0106	0,0093	0,0041	$1,87^{a}$	0,153	$2,73^{b}$	0,150	$2,54^{b}$	0,153
3.Wing rib	20	0,1913			0,1913	1,83	0,223	233	0,223	2,39	0,223
4.Rump	65	0,0053	0,0577	0,0578	0,0034	$2,43^{a}$	0,235	$2,35^{b}$	0,230	$3,85^{b}$	0,234
5.Topside	38	0,0370			0,0370	$2,43^{a}$	0,220	$3,18^{a}$	0,220	$3,27^{b}$	0,241
6.Fillet	19	0,2372			0,2372	2,81	0,269	3,30	0,295	3,47	0,269
COOKED (MOIST HEAT)											
7.Silverside	33	0,0507			0,0507	$1,80^{a}$	0,235	$2,45^{ab}$	0,235	$2,66^{b}$	0,235
8.Thick flank	65	0,0060	0,2100	0,1343	0,0019	$2,18^{a}$	0,152	$2,86^{b}$	0,149	$3,15^{b}$	0,151
9.Chuck	43	0,0993	0,1334	0,1214	0,0921	2,29	0,204	2,68	0,200	2,99	0,204
10.Brisket	71	0,0018	0,0340	0,0234	0,0030	$1,52^{a}$	0,121	$1,80^{a}$	0,119	$2,27^{b}$	0,121
11.Neck	37	0,0302			0,0302	$1,96^{a}$	0,232	$2,59^{ab}$	0,232	$2,92^{b}$	0,232
12.Shoulder	38	0,0271			0,0271	$2,14^{a}$	0,182	$2,80^{b}$	0,182	$2,83^{b}$	0,182
13.Thin flank	63	0,0078	0,0168	0,0256	0,0284	$1,32^{a}$	0,117	$0,61^{ab}$	0,114	$1,84^{b}$	0,117
14.Fore shin	54	0,0031			0,0031	$2,19^{a}$	0,153	$2,82^{b}$	0,153	$3,07^{b}$	0,153
15.Hind shin	49	0,0206	0,0859		0,0110	$2,04^{a}$	0,134	$2,49^{b}$	0,131	$2,72^{b}$	0,134
16.Carcass*	48	0,0103			0,0103	$1,96^{a}$	0,167	$2,54^{b}$	0,152	$2,76^{b}$	0,152

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 17

Least Square Mean Values (± Standard Error of Mean) of Thiamin Content for Beef Cuts Obtained from Three Age Groups (n = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	51	0,0172	0,0030		0,2413	0,103	0,007	0,097	0,007	0,086	0,007
2.Loin	39	0,0690	0,0115		0,8056	0,105	0,006	0,105	0,006	0,100	0,006
3.Wing rib	0,8	0,9390			0,9390	0,101	0,007	0,100	0,007	0,097	0,007
4.Rump	46	0,0303	0,0246		0,0362	0,136^{a}	0,008	0,113^{ab}	0,008	0,105^{b}	0,008
5.Topside	33	0,2305	0,1089	0,1330	0,2102	0,116	0,006	0,108	0,006	0,100	0,006
4.Fillet	2	0,8645			0,8645	0,159	0,025	0,164	0,025	0,146	0,025
5.Silverside	8	0,5477			0,5477	0,108	0,008	0,117	0,008	0,100	0,008
8.Thick flank	7	0,5931			0,5931	0,110	0,009	0,112	0,009	0,100	0,009
9.Chuck	55	0,0259	0,0076	0,0168	0,5097	0,120	0,009	0,109	0,009	0,106	0,009
10.Brisket	63	0,0079	0,0441	0,1487	0,3906	0,105	0,008	0,100	0,008	0,089	0,008
11.Neck	72	0,0015	0,0075	0,0355	0,7209	0,110	0,008	0,103	0,008	0,101	0,008
12.Shoulder	59	0,0156	0,0037	0,0079	0,2762	0,125	0,009	0,122	0,008	0,106	0,008
13.Thin flank	22	0,3017	0,1271		0,4704	0,097	0,011	0,102	0,011	0,084	0,011
14.Fore shin	28	0,3311	0,0741	0,0997	0,8987	0,113	0,013	0,107	0,012	0,115	0,012
15,Hind shin	60	0,0126	0,0015	0,0029	0,4172	0,114	0,007	0,115	0,007	0,103	0,007
16.Carcass*	51	0,0223	0,0036		0,2793	0,116	0,007	0,110	0,006	0,100	0,006
COOKED (DRY HEAT)											
1.Prime rib	26	0,1190			0,1190	0,131	0,014	0,096	0,013	0,094	0,013
2.Loin	19	0,2090			0,2090	0,126	0,012	0,114	0,012	0,096	0,012
3.Wing rib	39	0,0699	0,0392		0,0821	0,124	0,009	0,104	0,009	0,093	0,009
4.Rump	16	0,2744			0,2744	0,136	0,014	0,112	0,014	0,105	0,014
5.Topside	13	0,3436			0,3436	0,127	0,012	0,109	0,012	0,101	0,012
6.Fillet	10	0,4723			0,4723	0,145	0,015	0,119	0,015	0,126	0,015
COOKED (MOIST HEAT)											
7.Silverside	19	0,2059			0,2059	0,125	0,011	0,117	0,011	0,197	0,011
8.Thick flank	18	0,2374			0,2374	0,130	0,013	0,106	0,013	0,100	0,013
9.Chuck	33	0,1242	0,1119		0,0936	0,133	0,012	0,109	0,012	0,093	0,012
10.Brisket	18	0,2364			0,2364	0,123	0,012	0,105	0,012	0,094	0,012
11.Neck	14	0,3182			0,3182	0,121	0,014	0,099	0,014	0,092	0,014
12.Shoulder	14	0,3165			0,3165	0,125	0,014	0,104	0,014	0,095	0,014
13.Thin flank	21	0,1719			0,1719	0,123	0,011	0,098	0,011	0,093	0,011
14.Fore shin	15	0,2979			0,2979	0,126	0,013	0,108	0,013	0,196	0,013
15.Hind shin	13	0,3666			0,3666	0,129	0,014	0,107	0,014	0,102	0,014
16.Carcass*	35	0,1185	0,1127		0,0816	0,135	0,012	0,105	0,011	0,095	0,011

[1] p-values are of the full model, if not significant ($p \geq 0{,}15$) covariant was removed from the model starting with X ^{2} and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0{,}05$)

TABLE 18

Least Square Mean Values (± Standard Error of Means) of Riboflavin Content for Beef Cuts Obtained from Three Age Groups ($n = 18$) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	19	0,1984			0,1984	0,088	0,012	0,120	0,012	0,104	0,012
2.Loin	15	0,3098			0,3098	0,089	0,015	0,122	0,015	0,104	0,015
3.Wing rib	44	0,0897	0,0435	0,0308	0,3812	0,083	0,007	0,091	0,007	0,097	0,007
4.Rump	9	0,5040			0,5040	0,104	0,013	$0,123^{ab}$	0,013	$0,121^{b}$	0,013
5.Topside	3	0,7975			0,7975	0,108	0,018	0,121	0,018	0,124	0,018
6.Fillet	3	0,7790			0,7790	0,164	0,019	0,147	0,019	0,164	0,019
7.Silverside	10	0,4714			0,4714	0,098	0,014	0,113	0,014	0,122	0,014
8.Thick flank	35	0,2009	0,0663	0,1063	0,7784	0,109	0,019	0,127	0,019	0,113	0,019
9.Chuck	5	0,6775			0,6775	0,159	0,034	0,128	0,034	0,118	0,034
10.Brisket	50	0,0497	0,1038	0,0644	0,2111	0,088	0,006	0,103	0,006	0,104	0,006
11.Neck	0,6	0,9550			0,9550	0,101	0,011	0,104	0,011	0,106	0,011
12.Shoulder	8	0,5272			0,5272	0,104	0,012	0,123	0,012	0,115	0,012
13.Thin flank	28	0,0842			0,0842	0,078	0,007	0,097	0,007	0,099	0,007
14.Fore shin	0,3	0,9745			0,9745	0,114	0,012	0,113	0,012	0,111	0,012
15.Hind shin	7	0,5673			0,5673	0,100	0,013	0,120	0,013	0,106	0,013
16.Carcass*	4	0,7559			0,7559	0,104	0,011	0,115	0,010	0,112	0,010
COOKED (DRY HEAT)											
1.Prime rib	6	0,6429			0,6429	0,129	0,014	0,111	0,013	0,118	0,013
2.Loin	6	0,6552			0,6552	0,116	0,011	0,106	0,011	0,119	0,011
3.Wing rib	7	0,2442			0,2442	0,115	0,011	0,196	0,011	0,122	0,011
4.Rump	9	0,5116			0,5116	0,121	0,012	0,108	0,012	0,127	0,012
5.Topside	5	0,6871			0,6871	0,118	0,013	0,109	0,013	0,125	0,013
6.Fillet	2	0,8781			0,8781	0,131	0,020	0,133	0,020	0,145	0,020
COOKED (MOIST HEAT)											
7.Silverside	6	0,6450			0,6450	0,128	0,016	0,110	0,016	0,126	0,016
8.Thick flank	5	0,6576			0,6576	0,118	0,014	0,106	0,014	0,125	0,014
9.Chuck	3	0,8296			0,8296	0,128	0,016	0,115	0,016	0,123	0,016
10.Brisket	9	0,5016			0,5016	0,122	0,013	0,101	0,013	0,114	0,013
11.Neck	5	0,6908			0,6908	0,122	0,012	0,109	0,012	0,120	0,012
12.Shoulder	7	0,5895			0,5895	0,126	0,013	0,108	0,013	0,121	0,013
13.Thin flank	3	0,7749			0,7749	0,107	0,015	0,094	0,015	0,109	0,015
14.Fore shin	5	0,6783			0,6783	0,119	0,014	0,107	0,014	0,123	0,014
15.Hind shin	0	0,4678			0,4678	0,124	0,012	0,103	0,012	0,121	0,012
16.Carcass*	7	0,5875			0,5875	0,122	0,014	0,105	0,013	0,122	0,013

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 19

Least Square Mean Values (± Standard Error of mean) of Nicotinamide Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	52	0,0137	0,0033		0,0770	4,96	0,248	4,31	0,244	4,12	0,245
2.Loin	55	0,0097	0,0017		0,1122	5,20	0,211	4,62	0,207	4,60	0,208
3.Wing rib	42	0,0505	0,0105		0,2347	5,11	0,235	4,74	0,231	4,52	0,232
4.Rump	9	0,4954			0,4954	4,73	0,269	4,66	0,269	4,30	0,269
5.Topside	34	0,2161	0,0633	0,0470	0,7001	5,11	0,363	5,01	0,359	4,69	0,358
4.Fillet	27	0,3481	0,0657	0,0822	0,6387	4,98	0,289	5,11	0,285	4,73	0,284
5.Silverside	10	0,4639			0,4639	5,09	0,345	4,94	0,345	4,49	0,345
8.Thick flank	21	0,3281	0,1232		0,5049	4,26	0,264	4,28	0,259	3,89	0,260
9.Chuck	48	0,0248	0,0055		0,1415	4,46	0,207	4,11	0,203	3,84	0,204
10.Brisket	66	0,0015	0,0008		0,0067	$4,43^{a}$	0,183	$3,96^{ab}$	0,180	$3,43^{b}$	0,180
11.Neck	33	0,1196	0,0240		0,4671	4,40	0,225	4,01	0,221	4,12	0,222
12.Shoulder	51	0,0160	0,0060		0,0467	$4,93^{a}$	0,209	$4,26^{b}$	0,205	$4,18^{b}$	0,206
13.Thin flank	40	0,0604	0,0142		0,3756	3,93	0,199	3,95	0,195	3,59	0,196
14.Fore shin	17	0,2513			0,2513	4,24	0,275	4,17	0,275	3,62	0,275
15.Hind shin	15	0,2961			0,2961	3,80	0,208	4,04	0,208	3,56	0,208
16.Carcass*	37	0,1058	0,0343		0,1959	4,62	0,217	4,33	0,193	4,05	0,194
COOKED (DRY HEAT)											
1.Prime rib	2	0,9007			0,9007	4,36	0,270	4,27	0,246	4,19	0,246
2.Loin	0,4	0,9680			0,9680	4,62	0,251	4,67	0,251	4,58	0,251
3.Wing rib	4	0,7578			0,7578	4,22	0,246	4,35	0,246	4,48	0,246
4.Rump	41	0,0567	0,0093		0,9359	4,24	0,183	4,27	0,179	4,18	0,182
5.Topside	21	0,1771			0,1771	4,45	0,215	4,45	0,215	4,97	0,215
6.Fillet	6	0,6189			0,6189	5,30	0,545	4,55	0,545	4,79	0,545
COOKED (MOIST HEAT)											
7.Silverside	13	0,3591			0,3591	4,40	0,471	5,25	0,471	4,40	0,471
8.Thick flank	2	0,8573			0,8573	4,06	0,268	4,10	0,268	4,26	0,268
9.Chuck	49	0,0518	0,1369	0,2573	0,2783	3,78	0,116	3,67	0,114	3,94	0,116
10.Brisket	48	0,0561	0,0537	0,1215	0,6810	3,85	0,151	3,67	0,148	3,72	0,150
11.Neck	22	0,1626			0,1626	4,12	0,136	3,76	0,136	4,07	0,136
12.Shoulder	3	0,7693			0,7693	4,13	0,172	3,97	0,172	4,12	0,172
13.Thin flank	9	0,4982			0,4982	3,66	0,210	3,50	0,210	3,86	0,210
14.Fore shin	4	0,7481			0,7481	3,78	0,217	3,98	0,217	4,00	0,217
15.Hind shin	6	0,6386			0,6386	3,75	0,110	3,83	0,110	3,90	0,110
16.Carcass*	2	0,8536			0,8536	4,10	0,155	4,09	0,141	4,20	0,141

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 20
Least Square Mean Values (± Standard Error of Mean) of Pyridoxine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	56	0,0219	0,0207	0,0324	0,0240	0,236^{a}	0,033	0,280^{ab}	0,032	0,378^{b}	0,032
2.Loin	39	0,0662	0,0977		0,0513	0,254	0,042	0,306	0,042	0,413	0,042
3.Wing rib	34	0,1094	0,0653		0,1240	0,247	0,045	0,318	0,044	0,388	0,044
4.Rump	32	0,1286	0,0673		0,1519	0,250	0,055	0,339	0,054	0,411	0,054
5.Topside	54	0,0099	0,1083		0,0052	0,252^{a}	0,037	0,293^{a}	0,036	0,447^{b}	0,036
4.Fillet	52	0,0147	0,0984		0,0080	0,253^{a}	0,042	0,333^{a}	0,041	0,470^{b}	0,041
5.Silverside	50	0,0055			0,0055	0,253^{a}	0,034	0,273^{a}	0,034	0,425^{b}	0,034
8.Thick flank	41	0,1179	0,0985	0,1342	0,0884	0,230	0,046	0,307	0,046	0,389	0,046
9.Chuck	39	0,0694	0,1173		0,0450	0,206^{a}	0,045	0,329^{ab}	0,044	0,381^{b}	0,044
10.Brisket	22	0,1580			0,1580	0,240	0,043	0,307	0,043	0,364	0,043
11.Neck	49	0,0549	0,0422	0,0504	0,0427	0,233^{a}	0,039	0,247^{a}	0,038	0,374^{b}	0,038
12.Shoulder	52	0,0369	0,0509	0,0783	0,0270	0,243^{a}	0,031	0,274^{a}	0,030	0,372^{b}	0,030
13.Thin flank	33	0,1276	0,1478		0,0924	0,230	0,043	0,297	0,042	0,375	0,042
14.Fore shin	42	0,1092	0,1097	0,1355	0,0687	0,218	0,043	0,292	0,043	0,376	0,043
15.Hind shin	52	0,0376	0,0427	0,0692	0,0355	0,233^{a}	0,032	0,281^{a}	0,031	0,364^{b}	0,031
16.Carcass*	29	0,0893			0,0893	0,252	0,043	0,295	0,039	0,387	0,039
COOKED (DRY HEAT)											
1.Prime rib	3	0,8253			0,8253	0,406	0,022	0,391	0,020	0,408	0,020
2.Loin	24	0,2571	0,0873		0,5950	0,392	0,014	0,378	0,014	0,398	0,014
3.Wing rib	15	0,2888			0,2888	0,397	0,015	0,374	0,015	0,409	0,015
4.Rump	40	0,0212			0,0212	0,418^{a}	0,012	0,369^{b}	0,012	0,376^{b}	0,012
5.Topside	19	0,1995			0,1995	0,428	0,014	0,392	0,014	0,407	0,014
6.Fillet	17	0,2599			0,2599	0,447	0,036	0,371	0,036	0,444	0,036
COOKED (MOIST HEAT)											
7.Silverside	18	0,4114	0,1187		0,8041	0,378	0,029	0,351	0,029	0,364	0,029
8.Thick flank	13	0,3406			0,3406	0,380	0,017	0,362	0,017	0,400	0,017
9.Chuck	37	0,1678	0,1356	0,1208	0,1470	0,406	0,016	0,358	0,016	0,386	0,016
10.Brisket	6	0,6142			0,6142	0,375	0,013	0,383	0,013	0,365	0,013
11.Neck	0,7	0,9476			0,9476	0,355	0,024	0,366	0,024	0,358	0,024
12.Shoulder	16	0,2784			0,2784	0,408	0,013	0,376	0,013	0,392	0,013
13.Thin flank	2	0,8765			0,8765	0,346	0,023	0,362	0,023	0,356	0,023
14.Fore shin	22	0,3064	0,1400		0,6158	0,385	0,013	0,368	0,013	0,380	0,013
15.Hind shin	4	0,7463			0,7463	0,390	0,016	0,375	0,016	0,375	0,016
16.Carcass*	4	0,7613			0,7613	0,382	0,011	0,373	0,010	0,383	0,010

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 21

Least Square Mean Values (± Standard Error of Mean) of Folic Acid Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	47	0,0082			0,0082	8,02^{a}	1,323	9,96^{a}	1,323	14,70^{b}	1,323
2.Loin	58	0,0016			0,0016	8,95^{a}	1,099	11,29^{a}	1,099	15,86b	1,099
3.Wing rib	45	0,0111			0,0111	9,11^{a}	1,181	10,61^{a}	1,181	14,77^{b}	1,181
4.Rump	36	0,0347			0,0347	9,15	1,321	11,17	1,321	14,53	1,321
5.Topside	38	0,0269			0,0269	9,36^{a}	1,235	11,18^{ab}	1,235	14,60^{b}	1,235
4.Fillet	21	0,1765			0,1765	11,03	1,807	11,33	1,807	15,54	1,807
5.Silverside	38	0,0294			0,0294	9,45^{a}	1,407	11,50^{ab}	1,407	15,34^{b}	1,407
8.Thick flank	42	0,0161			0,0161	9,54^{a}	1,378	10,84^{a}	1,378	15,68^{b}	1,378
9.Chuck	61	0,0009			0,0009	8,51^{a}	1,033	10,93^{a}	1,033	15,47^{b}	1,033
10.Brisket	61	0,0035	0,0928		0,0016	8,17^{a}	1,086	10,88^{a}	1,067	15,20^{b}	1,071
11.Neck	57	0,0018			0,0018	8,35^{a}	1,106	10,39^{a}	1,106	15,14^{b}	1,106
12.Shoulder	42	0,0174			0,0174	8,57^{a}	1,266	11,29^{ab}	1,266	14,43^{b}	1,266
13.Thin flank	49	0,0066			0,0066	8,85^{a}	1,302	10,44^{a}	1,302	15,51^{b}	1,302
14.Fore shin	62	0,0030	0,0741		0,0014	8,00^{a}	1,075	10,85^{a}	1,056	15,06^{b}	1,060
15.Hind shin	43	0,0149			0,0149	8,26^{a}	1,346	10,39^{a}	1,346	14,54^{b}	1,346
16.Carcass*	47	0,0115			0,0115	9,02^{a}	1,303	10,89^{a}	1,190	15,03^{b}	1,190
COOKED (DRY HEAT)											
1.Prime rib	12	0,4058			0,4058	13,44	0,526	14,02	0,480	14,43	0,480
2.Loin	27	0,0912			0,0912	12,78	0,513	14,07	0,513	14,41	0,513
3.Wing rib	17	0,2412			0,2412	13,52	0,571	14,71	0,571	14,79	0,571
4.Rump	19	0,3750	0,1250		0,5606	13,22	0,561	14,06	0,550	13,84	0,560
5.Topside	25	0,1154			0,1154	12,89	0,541	14,52	0,541	14,15	0,541
6.Fillet	29	0,1740	0,0836		0,2684	13,65	0,664	13,00	0,650	14,57	0,662
COOKED (MOIST HEAT)											
7.Silverside	12	0,3707			0,3707	12,94	0,581	13,58	0,581	14,13	0,581
8.Thick flank	49	0,0522	0,0745	0,0831	0,0329	12,61^{a}	0,574	14,14^{ab}	0,562	15,07^{b}	0,573
9.Chuck	28	0,0876			0,0876	12,40	0,610	14,08	0,610	14,29	0,610
10.Brisket	15	0,3081			0,3081	13,15	0,497	14,21	0,497	14,01	0,497
11.Neck	11	0,4075			0,4075	12,52	0,752	13,79	0,752	13,81	0,752
12.Shoulder	2	0,8327			0,8327	13,81	0,522	14,06	0,522	14,26	0,522
13.Thin flank	36	0,0334			0,0334	12,32^{a}	0,507	13,90^{b}	0,507	14,30^{b}	0,507
14.Fore shin	28	0,0830			0,0830	13,22	0,344	13,38	0,344	14,32	0,344
15.Hind shin	41	0,1167	0,0421	0,0326	0,1943	12,85	0,540	14,01	0,529	14,25	0,538
16.Carcass*	30	0,0842			0,0842	12,85	0,435	14,01	0,397	14,20	0,397

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 22

Least Square Mean Values (± Standard Error of Mean) of Cyanocobalamin Content for Beef Cuts Obtained from Three Age Groups (n = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	34	0,0425			0,0425	1,13^{a}	0,107	1,37^{ab}	0,107	1,56^{b}	0,107
2.Loin	32	0,0550			0,0550	1,08	0,136	1,47	0,136	1,57	0,136
3.Wing rib	28	0,0839			0,0839	1,14	0,097	1,34	0,097	1,47	0,097
4.Rump	17	0,2556			0,2556	1,52	0,163	1,76	0,163	1,92	0,163
5.Topside	33	0,0511			0,0511	1,24	0,096	1,45	0,096	1,60	0,096
4.Fillet	24	0,2610	0,1340		0,2558	1,76	0,228	2,15	0,224	2,31	0,225
5.Silverside	47	0,0626	0,0851	0,0720	0,0672	1,33	0,102	1,48	0,100	1,70	0,100
8.Thick flank	26	0,1040			0,1040	1,36	0,122	1,70	0,122	1,71	0,122
9.Chuck	6	0,5915			0,5915	1,55	0,166	1,70	0,166	1,79	0,166
10.Brisket	37	0,0300			0,0300	1,31^{a}	0,098	1,42^{ab}	0,098	1,71^{b}	0,098
11.Neck	27	0,0998			0,0998	1,46	0,157	1,62	0,157	1,97	0,157
12.Shoulder	15	0,2905			0,2905	1,64	0,202	1,77	0,202	2,09	0,202
13.Thin flank	32	0,0568			0,0568	1,17	0,121	1,44	0,121	1,62	0,121
14.Fore shin	4	0,7153			0,7153	1,64	0,158	1,82	0,158	1,74	0,158
15.Hind shin	13	0,3421			0,3421	1,49	0,127	1,57	0,127	1,76	0,127
16.Carcass*	31	0,0737			0,0737	1,34	0,125	1,58	0,114	1,77	0,114
COOKED (DRY HEAT)											
1.Prime rib	0,3	0,9766			0,9766	1,95	0,134	1,96	0,123	1,92	0,123
2.Loin	55	0,0257	0,0033	0,0033	0,3180	2,04	0,078	2,09	0,076	1,93	0,077
3.Wing rib	22	0,4795	0,0798	0,0820	0,9741	1,91	0,118	1,94	0,116	1,90	0,118
4.Rump	60	0,0010			0,0010	2,06^{a}	0,059	2,16^{a}	0,059	2,45^{b}	0,059
5.Topside	11	0,4147			0,4147	1,92	0,124	2,16	0,124	2,05	0,124
6.Fillet	10	0,4423			0,4423	2,35	0,176	2,52	0,176	2,68	0,176
COOKED (MOIST HEAT)											
7.Silverside	4	0,7647			0,7647	1,87	0,163	2,04	0,163	1,95	0,163
8.Thick flank	13	0,3607			0,3607	1,90	0,123	2,15	0,123	2,08	0,123
9.Chuck	59	0,0053	0,0258		0,0381	2,05^{a}	0,055	2,22^{ab}	0,054	2,27^{b}	0,055
10.Brisket	6	0,6144			0,6144	2,07	0,111	1,95	0,111	2,10	0,111
11.Neck	26	0,2312	0,1036		0,6207	1,87	0,141	2,07	0,139	1,97	0,141
12.Shoulder	16	0,2612			0,2612	1,99	0,107	2,19	0,107	2,24	0,107
13.Thin flank	41	0,0536	0,1055		0,1584	1,84	0,085	2,02	0,083	2,08	0,084
14.Fore shin	11	0,4037			0,4037	2,00	0,119	2,21	0,119	2,20	0,119
15.Hind shin	8	0,5273			0,5273	1,91	0,124	2,11	0,124	2,03	0,124
16.Carcass*	10	0,4714			0,4714	1,97	0,101	2,10	0,092	2,13	0,092

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X ^{2} and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 23

Least Square Mean Values (± Standard Error of Mean) of Biotin Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	31	0,0655			0,0655	1,72	0,162	1,99	0,162	2,31	0,162
2.Loin	22	0,1623			0,1623	1,83	0,185	1,81	0,185	2,28	0,185
3.Wing rib	54	0,0030			0,0030	1,77^{a}	0,198	1,88^{a}	0,198	2,83^{b}	0,198
4.Rump	37	0,0303			0,0303	2,10^{a}	0,173	1,97^{a}	0,173	2,66^{b}	0,173
5.Topside	40	0,0209			0,0209	1,89^{a}	0,189	1,89^{a}	0,189	2,62^{b}	0,189
4.Fillet	39	0,0247			0,0247	2,79^{ab}	0,360	2,27^{a}	0,360	3,81^{b}	0,360
5.Silverside	36	0,0363			0,0363	2,05^{ab}	0,200	1,82^{a}	0,200	2,61^{b}	0,200
8.Thick flank	44	0,0133			0,0133	1,80^{a}	0,197	1,95^{a}	0,197	2,69^{b}	0,197
9.Chuck	18	0,2248			0,2248	2,06	0,216	2,01	0,216	2,51	0,216
10.Brisket	59	0,0158	0,0673	0,1008	0,0069	1,86^{a}	0,177	2,01^{a}	0,175	2,75^{b}	0,174
11.Neck	22	0,1631			0,1631	1,84	0,170	1,93	0,170	2,30	1,70
12.Shoulder	19	0,1995			0,1995	2,06	0,168	2,02	0,168	2,43	0,168
13.Thin flank	17	0,2413			0,2413	1,84	0,168	1,97	0,168	2,25	0,168
14.Fore shin	34	0,0443			0,0443	1,82^{a}	0,174	1,78^{a}	0,174	2,39^{b}	0,174
15.Hind shin	24	0,1243			0,1243	2,00	0,189	2,05	0,189	2,53	0,189
16.Carcass*	36	0,0456			0,0456	1,99^{a}	0,185	1,95^{a}	0,169	2,55^{b}	0,169
COOKED (DRY HEAT)											
1.Prime rib	4	0,7379			0,7379	1,95	0,128	2,08	0,117	2,04	0,117
2.Loin	2	0,8773			0,8773	1,92	0,157	2,03	0,157	2,00	0,157
3.Wing rib	2	0,8895			0,8895	1,89	0,127	1,95	0,127	1,97	0,127
4.Rump	3	0,7692			0,7692	2,01	0,124	2,06	0,124	2,14	0,124
5.Topside	2	0,8352			0,8352	2,14	0,171	2,03	0,171	1,99	0,171
6.Fillet	2	0,8927			0,8927	2,71	0,256	2,81	0,256	2,88	0,256
COOKED (MOIST HEAT)											
7.Silverside	7	0,5885			0,5885	1,96	0,130	2,12	0,130	1,94	0,130
8.Thick flank	2	0,8323			0,8323	1,94	0,159	2,04	0,159	2,08	0,159
9.Chuck	3	0,8024			0,8024	2,08	0,128	2,16	0,128	2,04	0,128
10.Brisket	5	0,6603			0,6603	1,84	0,141	1,98	0,141	2,01	0,141
11.Neck	0,9	0,9366			0,9366	1,91	0,170	1,98	0,170	2,00	0,170
12.Shoulder	0,2	0,9841			0,9841	2,07	0,139	2,04	0,139	2,03	0,139
13.Thin flank	13	0,3664			0,3664	1,85	0,139	2,13	0,139	2,04	0,139
14.Fore shin	1	0,8990			0,8990	1,91	0,139	1,98	0,139	1,90	0,139
15.Hind shin	2	0,8454			0,8454	1,93	0,143	1,97	0,143	1,86	0,143
16.Carcass*	3	0,8310			0,8310	1,95	0,140	2,06	0,128	2,03	0,128

[1] p-values are of the full model, if not significant ($p \geq 0{,}15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0{,}05$)

TABLE 24

Least Square Mean Values (± Standard Error of Mean) of Pantothenate Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	35	0,1024	0,0398		0,1636	0,326	0,025	0,279	0,024	0,256	0,024
2.Loin	33	0,1215	0,0679		0,1535	0,301	0,020	0,283	0,019	0,244	0,020
3.Wing rib	45	0,0344	0,0273		0,0405	$0,323^{a}$	0,020	$0,267^{ab}$	0,020	$0,244^{b}$	0,020
4.Rump	60	0,0121	0,0126	0,0321	0,1198	0,353	0,023	0,284	0,023	0,297	0,023
5.Topside	45	0,0363	0,0380		0,0350	$0,323^{a}$	0,019	$0,268^{ab}$	0,019	$0,244^{b}$	0,019
4.Fillet	39	0,0644	0,0164		0,2343	0,424	0,040	0,323	0,039	0,366	0,039
5.Silverside	44	0,0369	0,0399		0,0356	$0,340^{a}$	0,023	$0,282^{ab}$	0,023	$0,243^{b}$	0,023
8.Thick flank	48	0,0250	0,0128		0,0456	$0,348^{a}$	0,023	$0,276^{b}$	0,023	$0,261^{b}$	0,023
9.Chuck	42	0,0481	0,0341		0,0571	0,351	0,022	0,298	0,022	0,269	0,022
10.Brisket	49	0,0202	0,0160		0,0281	$0,355^{a}$	0,026	$0,282^{ab}$	0,026	$0,243^{b}$	0,026
11.Neck	54	0,0303	0,0137	0,0300	0,3432	0,331	0,022	0,286	0,022	0,291	0,022
12.Shoulder	54	0,0277	0,0413	0,1038	0,2546	0,340	0,024	0,290	0,023	0,289	0,023
13.Thin flank	52	0,0375	0,0170	0,0386	0,4719	0,322	0,021	0,297	0,021	0,285	0,021
14.Fore shin	53	0,0119	0,0104		0,0173	$0,402^{a}$	0,028	$0,283^{b}$	0,027	$0,294^{b}$	0,028
15.Hind shin	47	0,0634	0,0323	0,0545	0,1654	0,354	0,026	0,285	0,026	0,290	0,026
16.Carcass*	61	0,0164	0,0261	0,0685	0,1157	0,322	0,019	0,288	0,017	0,265	0,016
COOKED (DRY HEAT)											
1.Prime rib	3	0,7887			0,7887	0,249	0,006	0,246	0,005	0,244	0,005
2.Loin	17	0,4409	0,1340		0,6531	0,250	0,006	0,243	0,006	0,243	0,006
3.Wing rib	5	0,6669			0,6669	0,252	0,007	0,243	0,007	0,249	0,007
4.Rump	11	0,4281			0,4281	0,260	0,006	0,250	0,006	0,258	0,006
5.Topside	6	0,6138			0,6138	0,256	0,006	0,247	0,006	0,252	0,006
6.Fillet	11	0,4177			0,4177	0,298	0,018	0,294	0,018	0,267	0,018
COOKED (MOIST HEAT)											
7.Silverside	9	0,5131			0,5131	0,240	0,010	0,256	0,010	0,247	0,010
8.Thick flank	18	0,2241			0,2241	0,266	0,006	0,251	0,006	0,258	0,006
9.Chuck	34	0,0462			0,0462	$0,273^{a}$	0,007	$0,252^{b}$	0,007	$0,248^{b}$	0,007
10.Brisket	5	0,7098			0,7098	0,248	0,009	0,242	0,009	0,253	0,009
11.Neck	2	0,8385			0,8385	0,244	0,006	0,246	0,006	0,249	0,006
12.Shoulder	41	0,0190			0,0190	$0,271^{a}$	0,005	$0,262^{ab}$	0,005	$0,248^{b}$	0,005
13.Thin flank	2	0,8473			0,8473	0,259	0,021	0,262	0,021	0,246	0,021
14.Fore shin	0,9	0,9348			0,9348	0,264	0,006	0,262	0,006	0,261	0,006
15.Hind shin	6	0,6310			0,6310	0,254	0,006	0,246	0,006	0,250	0,006
16.Carcass*	4	0,7405			0,7405	0,258	0,006	0,255	0,006	0,252	0,006

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 25

Least Square Mean Values (± Standard Error of mean) of Myristic Acid ($C_{14:0}$) for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						MEAN	SEM	MEAN	SEM	MEAN	SEM
RAW											
1.Prime rib	87	0,0001	0,0001		0,1535	0,51	0,031	0,46	0,030	0,55	0,030
2.Loin	78	0,0001	0,0001		0,0271	$0,45^a$	0,035	$0,33^b$	0,034	$0,46^a$	0,034
3.Wing rib	67	0,0011	0,0002		0,7600	0,52	0,053	0,49	0,052	0,54	0,052
4.Rump	84	0,0001	0,0001		0,0113	$0,48^a$	0,026	$0,36^b$	0,026	$0,44^a$	0,026
5.Topside	72	0,0015	0,0276	0,0536	0,0031	$0,44^a$	0,025	$0,29^b$	0,025	$0,33^b$	0,025
6.Fillet	66	0,0049	0,2725	0,1117	0,1157	0,23	0,019	0,17	0,019	0,19	0,019
7.Silverside	71	0,0004	0,0002		0,1938	0,32	0,020	0,27	0,020	0,30	0,020
8.Thick flank	68	0,0009	0,0141		0,0052	$0,35^a$	0,026	$0,21^b$	0,026	$0,26^b$	0,026
9.Chuck	89	0,0001	0,0011	0,0196	0,2254	0,32	0,017	0,33	0,017	0,36	0,016
10.Brisket	83	0,0001	0,0001		0,2737	0,64	0,034	0,57	0,033	0,57	0,034
11.Neck	85	0,0001	0,5339	0,1119	0,0201	$0,45^a$	0,022	$0,37^b$	0,022	$0,35^b$	0,022
12.Shoulder	70	0,0006	0,0001		0,6728	0,32	0,021	0,32	0,021	0,34	0,021
13.Thin flank	72	0,0004	0,0001		0,9925	0,66	0,051	0,66	0,050	0,66	0,50
14.Fore Shin	63	0,0025	0,0114		0,0264	$0,26^a$	0,019	$0,18^b$	0,019	$0,20^b$	0,019
15.Hind Shin	58	0,0054	0,0439		0,0220	$0,38^a$	0,026	$0,31^{ab}$	0,026	$0,26^b$	0,026
16.Carcass*	93	0,0001	0,0001		0,1436	0,43	0,016	0,38	0,014	0,41	0,014
COOKED (DRY HEAT)											
1.Prime rib	59	0,0052	0,0008		0,5678	0,51	0,050	0,47	0,049	0,55	0,049
2.Loin	71	0,0005	0,0002		0,2092	0,47	0,050	0,34	0,049	0,42	0,050
3.Wing rib	83	0,0001	0,6669	0,1360	0,1456	0,54	0,040	0,43	0,039	0,51	0,040
4.Rump	88	0,0001	0,0001		0,0489	$0,53^a$	0,028	$0,51^{ab}$	0,027	$0,43^b$	0,028
5.Topside	62	0,0030	0,0120		0,0361	$0,34^a$	0,024	$0,26^b$	0,024	$0,25^b$	0,024
6.Fillet	40	0,0629	0,0278		0,1513	0,22	0,019	0,21	0,019	0,26	0,019
COOKED (MOIST HEAT)											
7.Silverside	42	0,0477	0,0086		0,3891	0,29	0,038	0,29	0,037	0,35	0,038
8.Thick flank	46	0,0318	0,0066		0,7911	0,21	0,021	0,19	0,020	0,21	0,021
9.Chuck	73	0,0003	0,0001		0,0817	0,40	0,042	0,29	0,041	0,42	0,042
10.Brisket	69	0,0008	0,0001		0,5913	0,68	0,056	0,61	0,055	0,66	0,056
11.Neck	56	0,0078	0,0074		0,0980	0,48	0,048	0,32	0,047	0,43	0,048
12.Shoulder	62	0,0028	0,0037		0,0648	0,40	0,034	0,27	0,033	0,33	0,034
13.Thin flank	76	0,0001	0,0001		0,1646	0,66	0,055	0,53	0,054	0,67	0,055
14.Fore shin	67	0,0012	0,0159		0,0043	$0,24^a$	0,016	$0,15^b$	0,015	$0,20^b$	0,016
15.Hind shin	82	0,0001	0,0097		0,0001	$0,42^a$	0,020	$0,25^b$	0,020	$0,28^b$	0,020
16.Carcass*	84	0,0001	0,0001		0,0855	0,47	0,030	0,37	0,026	0,43	0,027

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 26

Least Square Mean Values (± Standard Error of mean) of Palmitic Acid ($C_{16:0}$) for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						MEAN	SEM	MEAN	SEM	MEAN	SEM
RAW											
1.Prime rib	87	0,0001	0,0001		0,0038	3,82^{a}	0,157	4,16^{a}	0,154	4,72^{b}	0,154
2 Loin	77	0,0001	0,0001		0,0607	3,95	0,193	3,65	0,189	4,35	0,190
3.Wing rib	84	0,0001	0,0001		0,0489	4,11^{a}	0,186	4,38^{ab}	0,182	4,83^{b}	0,183
4.Rump	95	0,0001	0,0001	0,0057	0,0001	3,60^{a}	0,068	3,50^{a}	0,068	4,11^{b}	0,067
5.Topside	63	0,0028	0,0206	0,0541	0,0717	3,27	0,119	2,98	0,117	3,39	0,117
6.Fillet	38	0,0286			0,0286	2,09^{ab}	0,084	1,91^{a}	0,084	2,27^{b}	0,084
7.Silverside	70	0,0007	0,0003		0,0177	2,79^{a}	0,097	2,69^{a}	0,095	3,11^{b}	0,095
8.Thick flank	43	0,0441	0,0458		0,1905	2,95	0,197	2,42	0,193	2,77	0,194
9.Chuck	81	0,0001	0,0134	0,0954	0,0102	3,12^{a}	0,121	3,22^{a}	0,120	3,70^{b}	0,119
10.Brisket	89	0,0001	0,0001		0,4956	4,85	0,126	5,00	0,124	5,06	0,124
11.Neck	64	0,0021	0,0004		0,6909	3,58	0,147	3,50	0,145	3,40	0,145
12.Shoulder	69	0,0026	0,3874	0,1087	0,1569	2,89	0,126	3,07	0,125	3,26	0,124
13.Thin flank	71	0,0016	0,0158	0,0749	0,5353	5,25	0,264	5,37	0,261	5,66	0,260
14.Fore shin	56	0,0083	0,0362		0,0386	2,54^{a}	0,107	2,11^{b}	0,105	2,26^{ab}	0,105
15.Hind shin	5	0,6845			0,6845	3,08	0,192	3,07	0,192	2,87	0,192
16.Carcass*	95	0,0001	0,0010	0,0749	0,0019	3,58^{a}	0,067	3,58^{a}	0,060	3,93^{b}	0,059
COOKED (DRY HEAT)											
1.Prime rib	60	0,0040	0,0004		0,2429	3,97	0,285	4,31	0,279	4,70	0,284
2.Loin	83	0,0001	0,0934	0,5600	0,4342	4,22	0,235	4,00	0,230	4,43	0,234
3.Wing rib	82	0,0001	0,0001		0,1831	4,29	0,185	3,97	0,181	4,47	0,185
4.Rump	88	0,0001	0,0001		0,1803	4,22	0,148	4,39	0,145	3,99	0,147
5.Topside	53	0,0117	0,0038		0,6217	3,34	0,155	3,23	0,152	3,12	0,155
6.Fillet	52	0,0140	0,0621		0,0077	2,23^{a}	0,100	2,46^{a}	0,098	2,76^{b}	0,100
COOKED (MOIST HEAT)											
7.Silverside	71	0,0004	0,0001		0,0208	2,78^{a}	0,114	2,77^{a}	0,111	3,23^{b}	0,113
8.Thick flank	18	0,4237	0,1261		0,6200	2,59	0,132	2,67	0,130	2,77	0,132
9.Chuck	89	0,0001	0,0001		0,0530	3,99	0,153	3,75	0,150	4,35	0,152
10.Brisket	89	0,0001	0,0001		0,0492	5,15	0,149	5,19	0,146	5,67	0,148
11.Neck	73	0,0003	0,0001		0,4953	4,11	0,211	4,16	0,207	4,45	0,211
12.Shoulder	87	0,0001	0,0066	0,0841	0,1501	3,55	0,105	3,31	0,103	3,60	0,105
13.Thin flank	70	0,0006	0,0001		0,1160	5,54	0,294	6,02	0,288	6,49	0,293
14.Fore shin	36	0,0959	0,0213		0,4611	2,36	0,139	2,29	0,136	2,53	0,138
15.Hind shin	63	0,0023	0,0118		0,0156	3,14^{a}	0,108	2,63^{b}	0,106	2,84^{b}	0,108
16.Carcass*	96	0,0001	0,0001		0,0139	3,91^{a}	0,080	3,94^{a}	0,071	4,24^{b}	0,072

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

abc Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 27

Least Square Mean Values (± Standard Error of mean) of Stearic Acid ($C_{18:0}$) for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1. Prime rib	56	0,0085	0,0018		0,7842	0,71	0,087	0,68	0,86	0,62	0,086
2. Loin	59	0,0052	0,0012		0,3863	0,67	0,071	0,58	0,070	0,71	0,070
3. Wing rib	56	0,0078	0,0010		0,9261	0,69	0,085	0,73	0,083	0,72	0,084
4. Rump	50	0,0184	0,0073		0,4806	0,69	0,075	0,56	0,074	0,59	0,074
5. Topside	36	0,0337			0,0337	$0,57^{a}$	0,047	$0,41^{b}$	0,047	$0,40^{b}$	0,047
6. Fillet	23	0,1439			0,1439	0,29	0,023	0,25	0,023	0,22	0,023
7.Silverside	11	0,4243			0,4243	0,60	0,125	0,71	0,125	0,48	0,125
8. Thick flank	61	0,0033	0,0315		0,0168	$0,53^{a}$	0,042	$0,37^{b}$	0,042	$0,35^{b}$	0,042
9. Chuck	34	0,1089	0,0285		0,8755	0,48	0,055	0,44	0,054	0,45	0,054
10.Brisket	52	0,0141	0,0091		0,2899	1,06	0,127	0,88	0,125	0,77	0,125
11.Neck	57	0,0063	0,0194		0,0520	$0,63^{a}$	0,059	$0,49^{ab}$	0,058	$0,40^{b}$	0,059
12.Shoulder	49	0,0206	0,0108		0,3892	0,54	0,055	0,46	0,054	0,43	0,054
13.Thin flank	50	0,0193	0,0046		0,7481	0,92	0,112	0,89	0,110	0,80	0,111
14.Fore Shin	59	0,0046	0,0340		0,0220	$0,46^{a}$	0,035	$0,35^{ab}$	0,035	$0,30^{b}$	0,035
15.Hind shin	55	0,0096	0,0674		0,0303	$0,80^{a}$	0,068	$0,62^{ab}$	0,067	$0,52^{b}$	0,067
16.Carcass*	60	0,0200	0,0067	0,0153	0,9247	2,95	0,119	2,89	0,106	2,89	0,105
COOKED (DRY HEAT)											
1.Prime rib	71	0,0005	0,0001		0,0924	0,47	0,037	0,50	0,037	0,59	0,037
2.Loin	41	0,0518	0,0113		0,2144	0,37	0,049	0,40	0,048	0,50	0,048
3.Wing rib	91	0,0001	0,3909	0,0177	0,0514	$0,49^{ab}$	0,023	$0,47^{a}$	0,023	$0,55^{b}$	0,023
4.Rump	86	0,0001	0,0001		0,2650	0,46	0,034	0,51	0,033	0,43	0,034
5.Topside	47	0,0275	0,0066		0,8545	0,29	0,029	0,28	0,028	0,26	0,029
6.Fillet	5	0,6806			0,6806	0,25	0,023	0,22	0,023	0,23	0,023
COOKED (MOIST HEAT)											
7.Silverside	70	0,0007	0,0001		0,2296	0,42	0,045	0,48	0,044	0,54	0,045
8.Thick flank	3	0,7962			0,7962	0,29	0,040	0,25	0,40	0,26	0,040
9.Chuck	75	0,0007	0,2936	0,0604	0,2015	0,34	0,036	0,33	0,035	0,42	0,035
10.Brisket	78	0,0001	0,0001		0,0755	0,71	0,043	0,73	0,042	0,85	0,043
11.Neck	72	0,0014	0,2796	0,0793	0,1711	0,45	0,040	0,33	0,040	0,41	0,040
12.Shoulder	70	0,0021	0,1257	0,0311	0,7513	0,40	0,025	0,37	0,024	0,38	0,025
13.Thin flank	74	0,0002	0,0001		0,1929	0,68	0,073	0,54	0,072	0,73	0,073
14.Fore shin	54	0,0289	0,2703	0,1354	0,1564	0,30	0,024	0,24	0,024	0,28	0,024
15.Hind shin	72	0,0015	0,2749	0,1026	0,0282	$0,57^{a}$	0,028	$0,46^{b}$	0,028	$0,47^{b}$	0,028
16.Carcass*	64	0,0114	0,0219	0,0578	0,4796	3,13	0,122	3,19	0,108	3,00	0,110

[1] p-values are of the full model, if not significant (p ≥ 0,15) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly (p ≤ 0,05)

TABLE 28

Least Square Mean Values (± Standard Error of mean) of Palmitoleic ($C_{16:1}$) for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	50	0,0193	0,0023		0,6556	3,24	0,209	3,46	0,205	3,50	0,206
2.Loin	40	0,0624	0,0170		0,8055	3,07	0,225	2,88	0,221	2,90	0,222
3.Wing rib	57	0,0198	0,0468	0,1288	0,9684	3,44	0,197	3,47	0,195	3,40	0,194
4.Rump	38	0,1619	0,0379	0,0582	0,8544	2,99	0,164	3,03	0,162	2,91	0,161
5.Topside	33	0,2262	0,0279	0,0333	0,7187	2,49	0,160	2,40	0,158	2,28	0,158
6.Fillet	46	0,0726	0,1371	0,0998	0,0784	1,74	0,086	1,74	0,085	1,99	0,085
7.Silverside	1	0,9209			0,9209	1,92	0,125	1,88	0,125	1,95	0,125
8.Thick flank	5	0,6686			0,6686	2,17	0,262	1,84	0,262	1,96	0,262
9.Chuck	28	0,1958	0,0678		0,2865	2,68	0,177	3,00	0,174	3,07	0,175
10.Brisket	58	0,0165	0,0151	0,0308	0,2097	4,15	0,195	4,20	0,192	3,74	0,192
11.Neck	7	0,5623			0,5623	2,94	0,206	3,00	0,206	2,70	0,206
12.Shoulder	23	0,1379			0,1379	2,13	0,094	2,21	0,094	2,40	0,094
13.Thin flank	35	0,2011	0,0537	0,0848	0,8134	4,14	0,293	4,41	0,290	4,28	0,289
14.Fore shin	6	0,6164			0,6164	1,63	0,095	1,49	0,095	1,55	0,095
15.Hind shin	21	0,1774			0,1774	1,73	0,121	1,96	0,121	1,63	0,121
16.Carcass*	51	0,0215	0,0064		0,7166	0,63	0,077	0,60	0,068	0,55	0,069
COOKED (DRY HEAT)											
1.Prime rib	28	0,1970	0,0450		0,7230	3,40	0,223	3,66	0,218	3,53	0,222
2.Loin	57	0,0066	0,0060		0,2035	3,18	0,177	2,85	0,173	2,72	0,176
3.Wing rib	37	0,0840	0,0384		0,5948	3,66	0,233	3,43	0,228	3,33	0,232
4.Rump	74	0,0003	0,0006		0,0127	$3,67^a$	0,147	$3,89^a$	0,144	$3,18^b$	0,147
5.Topside	48	0,0596	0,0342	0,0395	0,1096	2,51	0,101	2,58	0,099	2,27	0,100
6.Fillet	43	0,0156			0,0156	$1,95^a$	0,126	2,34	0,126	$2,53^b$	0,126
COOKED (MOIST HEAT)											
7.Silverside	40	0,1342	0,0157	0,0197	0,6246	1,98	0,078	2,04	0,077	2,09	0,078
8.Thick flank	47	0,0665	0,0275	0,0189	0,2527	1,80	0,078	1,96	0,076	1,80	0,078
9.Chuck	31	0,1487	0,0862		0,5462	3,41	0,199	3,26	0,195	3,09	0,199
10.Brisket	44	0,0898	0,0623	0,1214	0,9421	4,26	0,237	4,23	0,232	4,15	0,236
11.Neck	31	0,1516	0,0431		0,4961	3,23	0,220	3,60	0,216	3,37	0,220
12.Shoulder	31	0,2798	0,0781	0,1088	0,8393	2,53	0,162	2,49	0,159	2,39	0,162
13.Thin flank	10	0,4380			0,4380	4,56	0,378	5,09	0,378	4,43	0,378
14.Fore shin	4	0,7617			0,7617	1,56	0,118	1,65	0,118	1,69	0,118
15.Hind shin	2	0,8512			0,8512	1,76	0,132	1,66	0,132	1,69	P0,132
16.Carcass*	87	0,0001	0,0001		0,2269	0,46	0,027	0,44	0,024	0,50	0,024

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABEL 29

Least Square Mean Values (± Standard Error of mean) of Oleic Acid ($C_{18:1}$) for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	86	0,0001	0,7969	0,1158	0,1278	6,28	0,362	7,30	0,358	7,23	0,357
2.Loin	93	0,0001	0,7654	0,0852	0,0107	$6,26^{a}$	0,256	$6,79^{ab}$	0,253	$7,56^{b}$	0,252
3.Wing rib	97	0,0001	0,1380	0,1314	0,0077	$6,83^{a}$	0,177	$7,57^{b}$	0,175	$7,73^{b}$	0,174
4.Rump	87	0,0001	0,0001		0,0326	$5,78^{a}$	0,241	$6,19^{ab}$	0,237	$6,79^{b}$	0,238
5.Topside	85	0,0001	0,0001		0,6109	5,35	0,143	5,27	0,141	5,47	0,141
6.Fillet	63	0,0027	0,0004		0,5754	3,22	0,121	3,18	0,119	3,35	0,119
7.Silverside	77	0,0001	0,0001		0,1390	4,69	0,230	5,13	0,226	5,38	0,227
8.Thick flank	84	0,0001	0,6686	0,1196	0,6301	4,66	0,181	4,46	0,179	4,42	0,178
9.Chuck	82	0,0001	0,0001		0,1058	5,35	0,257	5,34	0,253	6,07	0,254
10.Brisket	88	0,0001	0,0001		0,7074	8,56	0,351	8,86	0,345	8,47	0,346
11.Neck	89	0,0001	0,0001		0,0950	5,92	0,214	6,01	0,210	5,36	0,211
12.Shoulder	84	0,0001	0,1837	0,0188	0,7024	4,96	0,261	5,27	0,258	5,07	0,257
13.Thin flank	80	0,0001	0,0001		0,3575	8,76	0,466	9,73	0,458	9,13	0,460
14.Fore Shin	83	0,0001	0,3856	0,0528	0,4822	4,02	0,146	4,12	0,144	4,28	0,143
15.Hind shin	79	0,0002	0,5680	0,1272	0,7553	5,98	0,223	5,77	0,220	5,77	0,220
16.Carcass*	97	0,0001	0,4557	0,0409	0,0653	6,00	0,140	6,38	0,124	6,48	0,123
COOKED (DRY HEAT)											
1.Prime rib	75	0,0002	0,0001		0,6062	0,659	0,441	7,13	0,432	7,16	0,440
2.Loin	86	0,0001	0,0001		0,4883	6,39	0,270	6,77	0,264	6,82	0,269
3.Wing rib	96	0,0001	0,6519	0,0100	0,7096	6,95	0,194	6,76	0,190	6,74	0,194
4.Rump	94	0,0001	0,8419	0,0460	0,0256	6,76	0,253	7,12	0,248	6,02	0,252
5.Topside	78	0,0001	0,0001		0,3326	5,28	0,239	5,30	0,234	4,84	0,238
6.Fillet	50	0,0186	0,0028		0,2781	3,48	0,150	3,78	0,147	3,79	0,150
COOKED (MOIST HEAT)											
7.Silverside	93	0,0001	0,7847	0,1067	0,0572	5,12	0,152	4,93	0,149	5,49	0,152
8.Thick flank	21	0,3282	0,0751		0,9458	4,50	0,320	4,53	0,314	4,65	0,320
9.Chuck	91	0,0001	0,0001		0,4828	6,61	0,240	6,58	0,235	6,23	0,239
10.Brisket	95	0,0001	0,0001		0,1409	9,01	0,227	9,11	0,223	9,65	0,227
11.Neck	87	0,0001	0,0001		0,7641	6,77	0,314	6,92	0,308	6,59	0,313
12.Shoulder	93	0,0001	0,0001		0,4543	5,80	0,155	6,02	0,152	5,77	0,155
13.Thin flank	87	0,0001	0,0001		0,1921	9,17	0,424	10,07	0,415	10,26	0,422
14.Fore shin	83	0,0001	0,4316	0,0670	0,2128	4,25	0,185	3,95	0,181	4,43	0,184
15.Hind shin	87	0,0001	0,6716	0,1193	0,0345	$5,98^{a}$	0,166	$5,34^{b}$	0,163	$5,41^{b}$	0,166
16.Carcass*	98	0,0001	0,0001		0,5398	6,57	0,130	6,76	0,115	6,74	0,118

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 30

Least Square Mean Values (± Standard Error of mean) of Linoleic Acid ($C_{18:2}$) for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	72	0,0004	0,0110		0,0022	$0,61^{a}$	0,063	$0,40^{b}$	0,061	$0,21^{b}$	0,062
2.Loin	39	0,0260			0,0260	$0,54^{a}$	0,089	$0,26^{b}$	0,089	$0,18^{b}$	0,089
3.Wing rib	78	0,0001	0,0022		0,0008	$0,60^{a}$	0,055	$0,38^{b}$	0,054	$0,21^{c}$	0,054
4.Rump	73	0,0003	0,0530		0,0007	$0,61^{a}$	0,057	$0,36^{b}$	0,056	$0,20^{b}$	0,056
5.Topside	61	0,0009			0,0009	$0,52^{a}$	0,053	$0,27^{b}$	0,053	$0,17^{b}$	0,053
6.Fillet	52	0,0038			0,0038	$0,44^{a}$	0,040	$0,34^{a}$	0,040	$0,21^{b}$	0,040
7.Silverside	82	0,0001	0,0150		0,0001	$0,40^{a}$	0,028	$0,27^{b}$	0,028	$0,14^{c}$	0,028
8.Thick flank	63	0,0023	0,1462		0,0035	$0,44^{a}$	0,047	$0,28^{b}$	0,046	$0,16^{b}$	0,046
9.Chuck	71	0,0005	0,0429		0,0014	$0,51^{a}$	0,046	$0,31^{b}$	0,045	$0,22^{b}$	0,045
10.Brisket	78	0,0001	0,0213		0,0002	$0,78^{a}$	0,070	$0,45^{b}$	0,069	$0,21^{c}$	0,069
11.Neck	69	0,0001			0,0001	$0,59^{a}$	0,055	$0,29^{b}$	0,055	$0,16^{b}$	0,055
12.Shoulder	79	0,0001	0,0147		0,0002	$0,53^{a}$	0,041	$0,28^{b}$	0,040	$0,20^{b}$	0,040
13.Thin flank	74	0,0002	0,0611		0,0005	$0,79^{a}$	0,076	$0,45^{b}$	0,075	$0,22^{b}$	0,075
14.Fore shin	57	0,0067	0,0503		0,0219	$0,36^{a}$	0,041	$0,29^{ab}$	0,040	$0,17^{b}$	0,040
15.Hind shin	77	0,0001	0,1302		0,0001	$0,49^{a}$	0,042	$0,27^{b}$	0,041	$0,13^{c}$	0,041
16,Carcass*	82	0,0001	0,0080		0,0003	$0,55^{a}$	0,045	$0,34^{b}$	0,040	$0,20^{c}$	0,040
COOKED (DRY HEAT)											
1.Prime rib	54	0,0029			0,0029	$0,51^{a}$	0,058	$0,29^{b}$	0,058	$0,17^{b}$	0,058
2.Loin	66	0,0013	0,0944		0,0029	$0,39^{a}$	0,044	$0,21^{b}$	0,043	$0,14^{b}$	0,043
3.Wing rib	65	0,0016	0,0313		0,0082	$0,50^{a}$	0,058	$0,31^{b}$	0,057	$0,19^{b}$	0,058
4.Rump	62	0,0030	0,0909		0,0075	$0,51^{a}$	0,060	$0,37^{a}$	0,059	$0,18^{b}$	0,060
5.Topside	73	0,0011	0,0748	0,0944	0,0008	$0,34^{a}$	0,029	$0,20^{b}$	0,028	$0,14^{b}$	0,029
6.Fillet	51	0,0047			0,0047	$0,45^{a}$	0,037	$0,30^{b}$	0,037	$0,24^{b}$	0,037
COOKED (MOIST HEAT)											
7.Silverside	62	0,0030	0,0829		0,0082	$0,38^{a}$	0,041	$0,29^{a}$	0,040	$0,16^{b}$	0,041
8.Thick flank	57	0,0018			0,0018	$0,31^{a}$	0,031	$0,18^{b}$	0,031	$0,12^{b}$	0,031
9.Chuck	54	0,0114	0,1356		0,0248	$0,38^{a}$	0,050	$0,24^{ab}$	0,049	$0,16^{b}$	0,050
10.Brisket	72	0,0004	0,0383		0,0014	$0,60^{a}$	0,057	$0,34^{b}$	0,056	$0,23^{b}$	0,057
11.Neck	68	0,0010	0,0503		0,0033	$0,38^{a}$	0,039	$0,21^{b}$	0,039	$0,15^{b}$	0,039
12.Shoulder	54	0,0030			0,0030	$0,41^{a}$	0,045	$0,28^{a}$	0,045	$0,14^{b}$	0,045
13.Thin flank	63	0,0023	0,0287		0,0131	$0,54^{a}$	0,073	$0,28^{b}$	0,071	$0,19^{b}$	0,072
14.Fore shin	78	0,0004	0,1567	0,1364	0,0001	$0,30^{a}$	0,020	$0,22^{b}$	0,020	$0,12^{c}$	0,020
15.Hind shin	63	0,0005			0,0005	$0,37^{a}$	0,032	$0,24^{b}$	0,032	$0,14^{c}$	0,032
16.Carcass*	70	0,0010	0,0928		0,0026	$0,45^{a}$	0,047	$0,27^{b}$	0,041	$0,17^{b}$	0,042

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 31

Least Square Mean Values (± Standard Error of mean) of Arachidonic Acid ($C_{20:4}$) for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	7	0,5611			0,5611	0,03	0,007	0,02	0,007	0,02	0,007
2.Loin	15	0,3015			0,3015	0,03	0,006	0,02	0,006	0,03	0,006
3.Wing rib	2	0,8480			0,8480	0,02	0,005	0,03	0,005	0,02	0,005
4.Rump	17	0,2596			0,2596	0,63	0,061	0,35	0,061	0,19	0,061
5.Topside	30	0,2957	0,0678	0,0797	0,6324	0,02	0,007	0,03	0,007	0,03	0,007
4.Fillet	50	0,0457	0,0553	0,0584	0,0613	0,05	0,006	0,06	0,006	0,03	0,006
5.Silverside	17	0,2574			0,2574	0,01	0,006	0,03	0,006	0,02	0,006
8.Thick flank	6	0,6197			0,6197	0,03	0,007	0,04	0,007	0,03	0,007
9.Chuck	0,3	0,9777			0,9777	0,03	0,006	0,03	0,006	0,03	0,006
10.Brisket	25	0,1199			0,1199	0,03	0,006	0,03	0,006	0,02	0,006
11.Neck	26	0,1063			0,1063	0,04	0,006	0,03	0,006	0,02	0,006
12.Shoulder	26	0,1046			0,1046	0,05	0,008	0,03	0,008	0,04	0,008
13.Thin flank	23	0,1363			0,1363	0,04	0,006	0,02	0,006	0,02	0,006
14.Fore shin	21	0,1767			0,1767	0,02	0,012	0,05	0,012	0,02	0,012
15.Hind shin	37	0,1689	0,1048	0,1434	0,3205	0,04	0,006	0,03	0,006	0,03	0,006
16.Carcass*	8	0,5594			0,5594	0,03	0,005	0,03	0,004	0,02	0,004
COOKED (DRY HEAT)											
1.Prime rib	23	0,2935	0,0688		0,9957	0,03	0,005	0,03	0,005	0,03	0,005
2.Loin	32	0,2562	0,0841	0,1239	0,6217	0,03	0,005	0,03	0,005	0,03	0,005
3.Wing rib	2	0,8453			0,8453	0,03	0,006	0,03	0,006	0,03	0,006
4.Rump	50	0,0194	0,0440		0,0184	$0,04^a$	0,005	$0,04^a$	0,004	$0,02^b$	0,004
5.Topside	23	0,1358			0,1358	0,04	0,008	0,02	0,008	0,02	0,008
6.Fillet	23	0,4453	0,1284	0,1002	0,8688	0,04	0,010	0,03	0,010	0,04	0,010
COOKED (MOIST HEAT)											
7.Silverside	14	0,3147			0,3147	0,02	0,009	0,04	0,009	0,03	0,009
8.Thick flank	32	0,1329	0,1239		0,0994	0,03	0,005	0,03	0,005	0,02	0,005
9.Chuck	20	0,1920			0,1920	0,02	0,006	0,02	0,006	0,04	0,006
10.Brisket	0,8	0,9452			0,9452	0,04	0,007	0,04	0,007	0,03	0,007
11.Neck	36	0,0885	0,0519		0,2604	0,03	0,006	0,02	0,006	0,03	0,006
12.Shoulder	17	0,2585			0,2585	0,02	0,005	0,04	0,005	0,03	0,005
13.Thin flank	4	0,7246			0,7246	0,03	0,015	0,03	0,015	0,04	0,015
14.Fore shin	3	0,8236			0,8236	0,02	0,006	0,03	0,006	0,03	0,006
15.Hind shin	0,8	0,9392			0,9392	0,04	0,007	0,03	0,007	0,03	0,007
16.Carcass*	16	0,5004	0,1468		0,9520	0,03	0,005	0,03	0,004	0,03	0,004

[1] p-values are of the full model, if not significant ($p \geq 0,15$) covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 32

Least Square Mean Values (± Standard Error of Mean) of Cholesterol Values for Beef Cuts Obtained from Three Age Groups ($n = 18$) (mg/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	11	0,4157			0,4157	68,18	2,796	66,34	2,796	62,87	2,796
2.Loin	16	0,2707			0,2707	62,49	2,529	60,66	2,529	56,59	2,529
3.Wing rib	12	0,3821			0,3821	68,92	3,832	63,30	3,832	61,47	3,832
4.Rump	14	0,3314			0,3314	72,46	4,340	65,07	4,340	63,64	4,340
5.Topside	49	0,0061			0,0061	70,15^{a}	3,008	61,67^{ab}	3,008	53,90^{b}	3,008
4.Fillet	49	0,0506	0,0422	0,0607	0,0577	66,68	2,502	59,79	2,471	57,50	2,464
5.Silverside	41	0,0190			0,0190	70,89^{a}	2,806	60,91^{b}	2,806	58,94^{b}	2,806
8.Thick flank	60	0,0134	0,1287	0,1442	0,0050	70,13^{a}	2,728	62,22^{ab}	2,695	54,47^{b}	2,687
9.Chuck	30	0,0672			0,0672	71,02	2,468	68,13	2,468	62,29	2,468
10.Brisket	31	0,2777	0,1202	0,1144	0,2627	75,15	3,463	74,23	3,421	67,49	3,411
11.Neck	53	0,0319	0,0927	0,1419	0,0161	75,99^{a}	2,673	76,38^{a}	2,641	65,20^{b}	2,633
12.Shoulder	30	0,0702			0,0702	69,50	2,663	69,20	2,663	61,12	2,663
13.Thin flank	44	0,0859	0,0712	0,0984	0,0620	70,29	2,556	70,58	2,525	62,29	2,517
14.Fore shin	71	0,0004	0,0198		0,0002	76,26^{a}	2,820	73,61^{a}	2,771	55,69^{b}	2,782
15.Hind shin	16	0,2663			0,2663	72,77	3,635	70,11	3,635	64,22	3,635
16.Carcass*	46	0,0898	0,1162	0,1283	0,0581	70,97	2,844	68,07	2,532	61,18	2,509
COOKED (DRY HEAT)											
1.Prime rib	5	0,7073			0,7073	81,72	2,091	82,37	2,091	79,97	2,091
2.Loin	16	0,2782			0,2782	83,10	3,129	83,57	3,129	76,94	3,129
3.Wing rib	13	0,3449			0,3449	75,91	2,523	81,29	2,523	78,32	2,523
4.Rump	45	0,0346	0,0067		0,1804	97,13	3,828	90,80	3,750	86,33	3,818
5.Topside	19	0,2021			0,2021	85,32	2,621	84,30	2,621	78,82	2,621
6.Fillet	22	0,3055	0,0798		0,6210	90,94	2,278	88,00	2,231	88,34	2,271
COOKED (MOIST HEAT)											
7.Silverside	12	0,3792			0,3792	85,40	3,235	87,66	3,235	81,11	3,235
8.Thick flank	39	0,0238			0,0238	87,25^{a}	1,937	86,95^{a}	1,937	79,71^{b}	1,937
9.Chuck	38	0,0763	0,0521		0,1120	97,29	3,422	100,95	3,352	90,23	3,412
10.Brisket	5	0,6669			0,6669	87,39	2,869	87,54	2,869	84,26	2,869
11.Neck	33	0,1264	0,0729		0,1257	101,02	3,836	94,51	3,758	88,90	3,825
12.Shoulder	14	0,3496			0,3496	88,73	3,649	92,47	3,331	85,38	3,331
13.Thin flank	25	0,1172			0,1172	78,26	3,501	85,36	3,501	74,50	3,501
14.Fore shin	9	0,4903			0,4903	84,65	2,081	87,03	2,081	83,50	2,081
15.Hind shin	28	0,0855			0,0855	92,52	3,548	85,84	3,548	80,44	3,548
16.Carcass*	34	0,1396	0,0927		0,1484	88,06	2,646	89,10	2,342	82,42	2,390

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in a row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 33

Least Square Mean Values (± Standard Error of Mean) of Alanine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	21	0,1796			0,1796	1,04	0,056	1,10	0,056	1,19	0,056
2.Loin	1	0,9652			0,9652	1,14	0,062	1,12	0,062	1,14	0,062
3.Wing rib	31	0,1420	0,0280		0,9819	1,10	0,062	1,09	0,061	1,10	0,062
4.Rump	54	0,0290	0,0074	0,0041	0,9200	1,09	0,040	1,11	0,039	1,11	0,039
5.Topside	5	0,6853			0,6853	1,09	0,047	1,10	0,047	1,14	0,047
6.Fillet	18	0,4131	0,1345		0,9403	1,10	0,049	1,08	0,048	1,09	0,048
7.Silverside	15	0,2969			0,2969	1,11	0,049	1,12	0,049	1,21	0,049
8.Thick flank	20	0,2425			0,2425	1,19	0,061	1,12	0,050	1,24	0,050
9.Chuck	16	0,2694			0,2694	1,06	0,046	1,09	0,046	1,17	0,046
10.Brisket	48	0,0333	0,0382		0,2115	0,97	0,055	1,03	0,049	1,11	0,049
11.Neck	44	0,0883	0,0970	0,0828	0,0592	1,10	0,044	1,06	0,044	1,22	0,044
12.Shoulder	13	0,3564			0,3564	1,10	0,034	1,16	0,034	1,16	0,034
13.Thin flank	19	0,5608	0,1193	0,1171	0,7577	1,15	0,101	1,26	0,100	1,19	0,100
14.Fore Shin	6	0,6373			0,6373	1,23	0,085	1,26	0,085	1,35	0,085
15.Hind Shin	7	0,5783			0,5783	1,23	0,071	1,29	0,071	1,34	0,071
16.Carcass*	36	0,0444			0,0444	$1,02^{a}$	0,040	$1,12^{ab}$	0,036	$1,17^{b}$	0,036
COOKED (DRY HEAT)											
1.Prime rib	44	0,0394	0,0539		0,2041	1,48	0,067	1,56	0,066	1,66	0,067
2.Loin	59	0,0141	0,0121	0,0272	0,4005	1,63	0,075	1,77	0,074	1,75	0,075
3.Wing rib	49	0,0200	0,1469		0,0421	$1,42^{a}$	0,072	$1,53^{ab}$	0,071	$1,17^{b}$	0,072
4.Rump	38	0,0716	0,0470		0,4012	1,51	0,100	1,53	0,098	1,69	0,100
5.Topside	44	0,0402	0,0777		0,0896	1,65	0,067	1,53	0,066	1,75	0,067
6.Fillet	35	0,0493			0,0493	$1,60^{ab}$	0,072	$1,48^{a}$	0,065	$1,74^{b}$	0,065
COOKED (MOIST HEAT)											
7.Silverside	26	0,1035			0,1035	1,57	0,063	1,58	0,063	1,75	0,063
8.Thick flank	42	0,1139	0,1337	0,1426	0,0879	1,60	0,080	1,56	0,079	1,81	0,080
9.Chuck	61	0,0117	0,0371	0,0616	0,0431	$1,47^{a}$	0,063	$1,61^{ab}$	0,062	$1,73^{b}$	0,063
10.Brisket	60	0,0135	0,0624	0,1229	0,0990	1,27	0,060	1,34	0,058	1,47	0,059
11.Neck	73	0,0003	0,0013		0,0108	$1,47^{a}$	0,055	$1,52^{a}$	0,054	$1,73^{b}$	0,055
12.Shoulder	54	0,0113	0,1270		0,0240	$1,62^{a}$	0,051	$1,67^{a}$	0,050	$1,84^{b}$	0,051
13.Thin flank	54	0,0108	0,0080		0,2348	1,28	0,095	1,28	0,093	1,49	0,095
14.Fore shin	32	0,0549			0,0549	1,66	0,079	1,76	0,079	1,95	0,079
15.Hind shin	50	0,0053			0,0053	$1,65^{a}$	0,049	$1,67^{a}$	0,049	$1,90^{b}$	0,049
16.Carcass*	60	0,0065	0,0257		0,0519	$1,48^{a}$	0,062	$1,53^{a}$	0,055	$1,70^{b}$	0,056

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

abc Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 34

Least Square Mean Values (± Standard Error of Mean) of Glycine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	40	0,0616	0,0442		0,3242	1,00	0,086	1,06	0,084	1,19	0,085
2.Loin	6	0,6512			0,6512	1,09	0,067	1,09	0,067	1,01	0,067
3.Wing rib	46	0,0290	0,0038		0,8529	1,07	0,060	1,03	0,059	1,03	0,059
4.Rump	43	0,0948	0,0185	0,0140	0,6210	1,09	0,103	1,06	0,102	0,95	0,102
5.Topside	6	0,6494			0,6494	0,97	0,041	0,96	0,041	1,01	0,041
6.Fillet	0,1	0,9905			0,9905	0,84	0,039	0,84	0,039	0,84	0,039
7.Silverside	23	0,1424			0,1424	1,02	0,065	1,17	0,065	1,19	0,065
8.Thick flank	5	0,7216			0,7216	1,16	0,058	1,12	0,047	1,17	0,047
9.Chuck	28	0,0865			0,0865	0,93	0,056	1,02	0,056	1,12	0,056
10.Brisket	50	0,0267	0,0312		0,2254	1,04	0,067	1,18	0,059	1,19	0,060
11.Neck	43	0,0986	0,0772	0,0564	0,1649	1,12	0,057	1,12	0,057	1,26	0,057
12.Shoulder	16	0,2612			0,2612	1,11	0,068	1,27	0,068	1,23	0,068
13.Thin flank	50	0,0462	0,0049	0,0056	0,6096	1,25	0,084	1,31	0,083	1,37	0,083
14.Fore Shin	22	0,3035	0,0730		0,9993	1,61	0,156	1,61	0,153	1,60	0,153
15.Hind Shin	2	0,8717			0,8717	1,72	0,137	1,75	0,137	1,82	0,137
16.Carcass*	24	0,1419			0,1419	1,04	0,053	1,15	0,048	1,19	0,048
COOKED (DRY HEAT)											
1.Prime rib	68	0,0010	0,0018		0,0553	1,39	0,046	1,53	0,045	1,55	0,046
2.Loin	72	0,0015	0,0036	0,0104	0,1101	1,54	0,084	1,78	0,082	1,77	0,084
3.Wing rib	78	0,0003	0,0032	0,0092	0,0084	1,46^{a}	0,042	1,55^{a}	0,042	1,69^{b}	0,042
4.Rump	43	0,0434	0,0133		0,7378	1,42	0,078	1,45	0,077	1,51	0,078
5.Topside	20	0,1849			0,1849	1,48	0,063	1,44	0,063	1,61	0,063
6.Fillet	51	0,0567	0,0843	0,1063	0,0504	1,27^{ab}	0,045	1,16^{a}	0,040	1,31^{b}	0,041
COOKED (MOIST HEAT)											
7.Silverside	60	0,0126	0,0409	0,0725	0,0604	1,45	0,047	1,53	0,046	1,63	0,047
8.Thick flank	57	0,0200	0,0486	0,0536	0,0211	1,45	0,072	1,53	0,070	1,77	0,071
9.Chuck	67	0,0041	0,0112	0,0246	0,0648	1,34	0,057	1,50	0,056	1,54	0,057
10.Brisket	83	0,0001	0,0031	0,0155	0,0116	1,38^{a}	0,051	1,47^{a}	0,050	1,63^{b}	0,051
11.Neck	83	0,0001	0,0001		0,0232	1,51^{a}	0,052	1,62^{a}	0,051	1,75^{b}	0,052
12.Shoulder	63	0,0023	0,0826		0,0061	1,60^{a}	0,060	1,77^{ab}	0,059	1,94^{b}	0,060
13.Thin flank	63	0,0080	0,0154	0,0371	0,1411	1,64	0,119	1,47	0,117	1,82	0,119
14.Fore shin	47	0,0647	0,0880	0,1386	0,2188	2,11	0,104	2,29	0,102	2,39	0,103
15.Hind shin	32	0,1394	0,1145		0,3694	2,23	0,114	2,22	0,112	2,43	0,114
16.Carcass*	88	0,0001	0,0022	0,0131	0,0025	1,51^{a}	0,035	1,57^{a}	0,031	1,71^{b}	0,031

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 35

Least Square Mean Values (± Standard Error of Mean) of Valine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	11	0,4255			0,4255	0,71	0,049	0,77	0,049	0,80	0,049
2.Loin	12	0,4005			0,4005	0,73	0,044	0,79	0,044	0,70	0,044
3.Wing rib	48	0,0252	0,0061		0,7012	0,72	0,040	0,76	0,040	0,73	0,040
4.Rump	35	0,1951	0,1253	0,0763	0,3906	0,70	0,029	0,76	0,028	0,73	0,028
5.Topside	1	0,9472			0,9472	0,75	0,041	0,76	0,041	0,75	0,041
6.Fillet	22	0,3156	0,1071		0,8799	0,82	0,054	0,78	0,053	0,79	0,053
7.Silverside	10	0,4633			0,4633	0,78	0,038	0,83	0,038	0,84	0,038
8.Thick flank	6	0,6835			0,6835	0,77	0,059	0,81	0,048	0,84	0,048
9.Chuck	20	0,3483	0,1289		0,7096	0,76	0,031	0,79	0,031	0,75	0,031
10.Brisket	66	0,0023	0,0065		0,0309	$0,62^{a}$	0,032	$0,75^{b}$	0,028	$0,67^{ab}$	0,028
11.Neck	36	0,1891	0,0813	0,0842	0,2160	0,69	0,028	0,73	0,027	0,76	0,027
12.Shoulder	9	0,4997			0,4997	0,69	0,039	0,76	0,039	0,70	0,039
13.Thin flank	1	0,9580			0,9580	0,75	0,085	0,73	0,085	0,77	0,085
14.Fore Shin	10	0,4660			0,4660	0,74	0,057	0,77	0,057	0,84	0,057
15.Hind Shin	28	0,0845			0,0845	0,66	0,032	0,77	0,032	0,74	0,032
16.Carcass*	37	0,0413			0,0413	$0,66^{a}$	0,030	$0,77^{b}$	0,028	$0,75^{b}$	0,028
COOKED (DRY HEAT)											
1.Prime rib	62	0,0032	0,0072		0,0654	1,01	0,045	1,06	0,044	1,17	0,045
2.Loin	24	0,1261			0,1261	1,07	0,058	1,22	0,057	1,19	0,058
3.Wing rib	65	0,0016	0,0584		0,0051	$0,97^{a}$	0,038	$1,04^{a}$	0,037	$1,18^{b}$	0,038
4.Rump	26	0,1091			0,1091	0,99	0,079	1,08	0,079	1,24	0,079
5.Topside	32	0,0571			0,0571	1,12	0,059	1,09	0,059	1,29	0,059
6.Fillet	64	0,0008			0,0008	$1,16^{a}$	0,038	$1,08^{a}$	0,035	$1,32^{b}$	0,035
COOKED (MOIST HEAT)											
7.Silverside	26	0,1074			0,1074	1,16	0,047	1,14	0,047	1,28	0,047
8.Thick flank	32	0,0572			0,0572	1,14	0,059	1,07	0,059	1,29	0,059
9.Chuck	49	0,0199	0,0656		0,0793	1,07	0,058	1,14	0,057	1,27	0,058
10.Brisket	60	0,0043	0,0028		0,2621	0,86	0,039	0,91	0,038	0,96	0,039
11.Neck	69	0,0007	0,0168		0,0046	$0,94^{a}$	0,039	$1,00^{a}$	0,038	$1,15^{b}$	0,039
12.Shoulder	22	0,1580			0,1580	1,04	0,054	1,11	0,054	1,19	0,054
13.Thin flank	62	0,0089	0,0073	0,0192	0,6146	0,85	0,050	0,82	0,049	0,89	0,050
14.Fore shin	63	0,0006			0,0006	$1,02^{a}$	0,036	$1,03^{a}$	0,036	$1,25^{b}$	0,036
15.Hind shin	43	0,0142			0,0142	$0,93^{a}$	0,040	$1,01^{ab}$	0,040	$1,12^{b}$	0,040
16.Carcass*	58	0,0089	0,0689		0,0335	$1,00^{a}$	0,044	$1,04^{a}$	0,039	$1,17^{b}$	0,040

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 36

Least Square Mean Values (± Standard Error of Mean) of Threonine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	27	0,2023	0,0890		0,6581	0,68	0,035	0,70	0,034	0,73	0,034
2.Loin	17	0,2377			0,2377	0,74	0,032	0,80	0,032	0,72	0,032
3.Wing rib	59	0,0049	0,0025		0,0971	0,71	0,039	0,79	0,038	0,66	0,038
4.Rump	32	0,2481	0,0695	0,0860	0,3054	0,74	0,033	0,78	0,032	0,71	0,032
5.Topside	15	0,2854			0,2854	0,75	0,030	0,82	0,030	0,77	0,030
6.Fillet	14	0,3209			0,3209	0,85	0,036	0,86	0,036	0,78	0,036
7.Silverside	53	0,0118	0,0254		0,0720	0,74	0,023	0,82	0,022	0,78	0,022
8.Thick flank	6	0,6644			0,6644	0,80	0,054	0,85	0,044	0,81	0,044
9.Chuck	30	0,1548	0,0546		0,6683	0,73	0,023	0,75	0,023	0,73	0,023
10.Brisket	75	0,0004	0,0004		0,0356	$0,60^{a}$	0,026	$0,70^{b}$	0,023	$0,62^{a}$	0,024
11Neck	22	0,1495			0,1495	0,69	0,026	0,71	0,026	0,76	0,026
12.Shoulder	28	0,0850			0,0850	0,72	0,028	0,81	0,028	0,74	0,028
13.Thin flank	1	0,9434			0,9434	0,69	0,076	0,66	0,076	0,66	0,076
14.Fore Shin	13	0,3405			0,3405	0,73	0,049	0,83	0,049	0,82	0,049
15.Hind Shin	46	0,0096			0,0096	$0,66^{a}$	0,027	$0,79^{b}$	0,027	$0,73^{ab}$	0,027
16.Carcass*	65	0,0096	0,0450	0,0744	0,0138	$0,66^{a}$	0,022	$0,77^{b}$	0,020	$0,72^{ab}$	0,020
COOKED (DRY HEAT)											
1.Prime rib	75	0,0002	0,0002		0,0396	$0,97^{a}$	0,030	$1,05^{ab}$	0,030	$1,09^{b}$	0,030
2.Loin	73	0,0013	0,0105	0,0323	0,0331	$1,09^{a}$	0,041	$1,26^{b}$	0,040	$1,17^{ab}$	0,041
3.Wing rib	74	0,0002	0,0027		0,0043	$0,94^{a}$	0,026	$1,05^{b}$	0,025	$1,09^{b}$	0,026
4.Rump	62	0,0090	0,0323	0,0794	0,2553	1,05	0,057	1,14	0,056	1,19	0,057
5.Topside	39	0,0652	0,0636		0,2562	1,17	0,050	1,16	0,049	1,27	0,050
6.Fillet	26	0,1167			0,1167	1,25	0,036	1,19	0,033	1,29	0,033
COOKED (MOIST HEAT)											
7.Silverside	17	0,2445			0,2445	1,10	0,043	1,16	0,043	1,20	0,043
8.Thick flank	33	0,2404	0,0730	0,0783	0,3741	1,17	0,048	1,14	0,047	1,23	0,048
9.Chuck	66	0,0050	0,0181	0,0462	0,1548	1,04	0,048	1,15	0,047	1,17	0,047
10.Brisket	75	0,0008	0,0116	0,0432	0,0598	0,80	0,026	0,90	0,026	0,86	0,026
11.Neck	82	0,0001	0,0003		0,0010	$0,92^{a}$	0,028	$1,05^{b}$	0,027	$1,11^{b}$	0,028
12.Shoulder	59	0,0049	0,0215		0,0392	$1,07^{a}$	0,027	$1,15^{b}$	0,027	$1,17^{b}$	0,027
13.Thin flank	61	0,0112	0,0298	0,0705	0,2510	0,70	0,039	0,79	0,038	0,79	0,039
14.Fore shin	56	0,0223	0,0453	0,0642	0,0499	$1,03^{a}$	0,038	$1,13^{ab}$	0,038	$1,19^{b}$	0,038
15.Hind shin	46	0,0101			0,0101	$0,93^{a}$	0,029	$1,02^{b}$	0,029	$1,07^{b}$	0,029
16.Carcass*	81	0,0003	0,0065	0,0227	0,0169	$0,98^{a}$	0,028	$1,08^{b}$	0,025	$1,10^{b}$	0,025

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 37

Least Square Mean Values (± Standard Error of Mean) of Serine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	29	0,1700	0,0480		0,7493	0,66	0,037	0,64	0,036	0,68	0,036
2.Loin	2	0,8885			0,8885	0,71	0,034	0,72	0,034	0,70	0,034
3.Wing rib	57	0,0071	0,0013		0,5635	0,67	0,036	0,70	0,035	0,65	0,036
4.Rump	36	0,1921	0,0267	0,0344	0,5929	0,71	0,035	0,72	0,035	0,67	0,035
5.Topside	8	0,5274			0,5274	0,70	0,024	0,73	0,024	0,73	0,024
6.Fillet	11	0,4315			0,4315	0,75	0,024	0,76	0,024	0,72	0,024
7.Silverside	43	0,0451	0,0279		0,3898	0,70	0,023	0,74	0,023	0,74	0,023
8.Thick flank	1	0,9651			0,9651	0,76	0,044	0,77	0,036	0,77	0,036
9.Chuck	28	0,1888	0,0519		0,8795	0,68	0,026	0,68	0,025	0,70	0,026
10.Brisket	66	0,0025	0,0019		0,1699	0,59	0,031	0,67	0,028	0,63	0,028
11.Neck	20	0,1967			0,1967	0,67	0,029	0,70	0,029	0,74	0,029
12.Shoulder	33	0,1203	0,0351		0,7345	0,72	0,030	0,75	0,029	0,73	0,029
13.Thin flank	1	0,9326			0,9326	0,67	0,069	0,65	0,069	0,68	0,069
14.Fore Shin	10	0,4691			0,4691	0,74	0,049	0,79	0,049	0,83	0,049
15.Hind Shin	36	0,0905	0,1038		0,2534	0,71	0,032	0,79	0,031	0,76	0,031
16.Carcass*	29	0,1985	0,0655		0,2747	0,38	0,501	1,37	0,445	1,44	0,447
COOKED (DRY HEAT)											
1.Prime rib	67	0,0011	0,0005		0,2899	0,91	0,036	0,97	0,035	1,00	0,036
2.Loin	85	0,0001	0,0002	0,0007	0,0148	1,03^{a}	0,028	1,17^{b}	0,027	1,10^{ab}	0,028
3.Wing rib	68	0,0010	0,0033		0,0299	0,91^{a}	0,030	0,99^{ab}	0,030	1,03^{b}	0,030
4.Rump	63	0,0079	0,0114	0,0269	0,2407	0,96	0,055	1,08	0,054	1,08	0,055
5.Topside	45	0,0833	0,0440	0,0809	0,7480	1,08	0,044	1,08	0,043	1,12	0,044
6.Fillet	37	0,2100	0,0522	0,0452	0,3559	1,03	0,057	1,09	0,050	1,15	0,051
COOKED (MOIST HEAT)											
7.Silverside	49	0,0555	0,0272	0,0385	0,1895	1,00	0,033	1,09	0,032	1,06	0,033
8.Thick flank	49	0,0517	0,0065	0,0071	0,4933	1,08	0,035	1,12	0,034	1,14	0,035
9.Chuck	84	0,0001	0,0006	0,0036	0,0349	0,96^{a}	0,028	1,07^{b}	0,028	1,05^{b}	0,028
10.Brisket	83	0,0001	0,0076	0,0485	0,0504	0,78^{a}	0,023	0,86^{b}	0,022	0,84^{ab}	0,023
11.Neck	78	0,0001	0,0002		0,0154	0,91^{a}	0,033	0,99^{ab}	0,032	1,07^{b}	0,033
12.Shoulder	56	0,0075	0,0310		0,0504	1,03^{a}	0,029	1,10^{ab}	0,028	1,14^{b}	0,029
13.Thin flank	61	0,0102	0,0477	0,1148	0,2519	0,72	0,041	0,78	0,040	0,82	0,041
14.Fore shin	68	0,0031	0,0042	0,0059	0,0170	1,03^{a}	0,030	1,13^{b}	0,029	1,17^{b}	0,030
15.Hind shin	70	0,0024	0,0825	0,1418	0,0052	0,98^{a}	0,022	1,06^{b}	0,022	1,11^{b}	0,022
16.Carcass*	87	0,0001	0,0006	0,0030	0,0168	0,93^{a}	0,022	1,02^{b}	0,020	1,03^{b}	0,020

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 38
Least Square Mean Values (± Standard Error of Mean) of Leucine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^{2} %	p-Value	X p-Value	X^{2} p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	30	0,0687			0,0687	1,18	0,068	1,30	0,068	1,43	0,068
2.Loin	9	0,5019			0,05019	1,33	0,061	1,42	0,061	1,35	0,061
3.Wing rib	55	0,0090	0,0029		0,4669	1,26	0,075	1,39	0,074	1,31	0,074
4.Rump	39	0,1414	0,0501	0,0613	0,1972	1,28	0,050	1,42	0,050	1,34	0,050
5.Topside	17	0,2430			0,2430	1,32	0,046	1,39	0,046	1,44	0,046
6.Fillet	2	0,8802			0,8802	1,51	0,085	1,46	0,085	1,51	0,085
7.Silverside	43	0,0442	0,0629		0,1852	1,34	0,056	1,45	0,055	1,49	0,055
8.Thick flank	13	0,4135			0,4135	1,40	0,091	1,48	0,075	1,56	0,075
9.Chuck	33	0,1214	0,0607		0,5404	1,34	0,054	1,43	0,053	1,40	0,053
10.Brisket	69	0,0014	0,0024		0,0626	1,06	0,059	1,27	0,053	1,21	0,053
11.Neck	39	0,0257			0,0257	1,24^{a}	0,048	1,36^{ab}	0,048	1,45^{b}	0,048
12.Shoulder	25	0,2391	0,0623		0,9658	1,36	0,063	1,38	0,062	1,38	0,062
13.Thin flank	3	0,8250			0,8250	1,25	0,145	1,21	0,145	1,34	0,145
14.Fore Shin	17	0,2484			0,2484	1,32	0,088	1,42	0,088	1,54	0,088
15.Hind Shin	50	0,0052			0,0052	1,16^{a}	0,049	1,38^{b}	0,049	1,41^{b}	0,049
16.Carcass*	70	0,0040	0,0757	0,1206	0,0051	1,17^{a}	0,043	1,38^{b}	0,038	1,39^{b}	0,038
COOKED (DRY HEAT)											
1. Prime rib	65	0,0017	0,0023		0,0923	1,85	0,072	1,93	0,070	2,09	0,071
2.Loin	64	0,0074	0,0242	0,0576	0,1506	2,01	0,095	2,26	0,093	2,25	0,095
3.Wing rib	61	0,0035	0,0308		0,0206	1,75^{a}	0,074	1,93^{b}	0,072	2,09^{b}	0,074
4.Rump	56	0,0083	0,0158		0,1029	1,91	0,118	2,06	0,116	2,30	0,118
5.Topside	43	0,0425	0,0845		0,1269	2,11	0,108	2,09	0,106	2,39	0,107
6.Fillet	49	0,0272	0,0753		0,0539	2,33^{ab}	0,097	2,15^{a}	0,086	2,48^{b}	0,087
COOKED (MOIST HEAT)											
7.Silverside	35	0,0402			0,0402	1,99^{a}	0,078	2,13^{ab}	0,078	2,30^{b}	0,078
8.Thick flank	37	0,0321			0,0321	2,10	0,103	2,05	0,103	2,44	0,103
9.Chuck	77	0,0004	0,0286	0,1033	0,0291	1,89^{a}	0,080	2,10^{ab}	0,078	2,24^{b}	0,079
10.Brisket	64	0,0021	0,0017		0,1828	1,46	0,068	1,61	0,067	1,64	0,068
11.Neck	85	0,0001	0,0001		0,0004	1,69^{a}	0,054	1,88^{b}	0,053	2,11^{c}	0,054
12.Shoulder	55	0,0099	0,0898		0,0288	1,95^{a}	0,067	2,14^{ab}	0,066	2,23^{b}	0,067
13.Thin flank	50	0,0176	0,0060		0,6096	1,34	0,091	1,45	0,090	1,47	0,091
14.Fore shin	53	0,116	0,1170		0,0263	1,91^{a}	0,078	1,99^{a}	0,077	2,24^{b}	0,078
15.Hind shin	54	0,0028			0,0028	1,68^{a}	0,066	1,87^{ab}	0,066	2,07^{b}	0,066
16.Carcass*	73	0,0006	0,0041		0,0161	1,78^{a}	0,070	1,95^{ab}	0,062	2,10^{b}	0,063

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^{2} and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly (p ≤ 0,05)

TABLE 39

Least Square Mean Values (± Standard Error of Mean) of Isoleucine Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	6	0,6092			0,6092	0,68	0,056	0,65	0,056	0,73	0,056
2.Loin	3	0,7870			0,7870	0,69	0,043	0,73	0,043	0,70	0,043
3.Wing rib	34	0,1076	0,0229		0,8323	0,69	0,045	0,71	0,044	0,67	0,044
4.Rump	6	0,6073			0,6073	0,68	0,038	0,66	0,038	0,72	0,038
5.Topside	2	0,8432			0,8432	0,73	0,043	0,73	0,043	0,76	0,043
6.Fillet	42	0,0467	0,0327		0,2793	0,82	0,040	0,73	0,039	0,79	0,039
7.Silverside	5	0,6821			0,6821	0,76	0,035	0,76	0,035	0,80	0,035
8.Thick flank	7	0,6457			0,6457	0,80	0,050	0,75	0,041	0,80	0,041
9.Chuck	7	0,5878			0,5878	0,73	0,040	0,71	0,040	0,77	0,040
10.Brisket	49	0,0293	0,0403		0,1641	0,59	0,041	0,70	0,036	0,64	0,037
11.Neck	57	0,0196	0,0148	0,0189	0,0179	0,65	0,021	0,63	0,021	0,72	0,021
12.Shoulder	7	0,6018			0,6018	0,66	0,034	0,70	0,034	0,66	0,034
13.Thin flank	6	0,6540			0,6540	0,70	0,079	0,60	0,079	0,66	0,079
14.Fore Shin	20	0,1829			0,1829	0,69	0,049	0,70	0,049	0,81	0,049
15.Hind Shin	28	0,0873			0,0873	0,61	0,030	0,70	0,030	0,69	0,030
16.Carcass*	24	0,1408			0,1408	0,64	0,028	0,69	0,026	0,72	0,026
COOKED (DRY HEAT)											
1.Prime rib	60	0,0039	0,0049		0,1131	0,93	0,046	0,95	0,045	1,07	0,046
2.Loin	29	0,1813	0,1439		0,4471	1,04	0,064	1,12	0,062	1,16	0,063
3.Wing rib	35	0,0396			0,0396	$0,75^{a}$	0,097	$0,94^{ab}$	0,097	$1,14^{b}$	0,097
4.Rump	21	0,1749			0,1749	0,96	0,081	1,02	0,081	1,18	0,081
5.Topside	14	0,3294			0,3294	1,12	0,077	1,03	0,077	1,20	0,077
6.Fillet	55	0,0035			0,0035	$1,21^{a}$	0,052	$1,00^{b}$	0,047	$1,26^{a}$	0,047
COOKED (MOIST HEAT)											
7.Silverside	20	0,1940			0,1940	1,16	0,060	1,04	0,060	1,20	0,060
8.Thick flank	19	0,2073			0,2073	1,12	0,068	1,01	0,068	1,19	0,068
9.Chuck	24	0,1278			0,1278	1,05	0,057	1,04	0,057	1,19	0,057
10.Brisket	37	0,0801	0,0430		0,4650	0,81	0,038	0,80	0,037	0,86	0,038
11.Neck	73	0,0003	0,0043		0,0042	$0,90^{a}$	0,029	$0,91^{a}$	0,028	$1,05^{b}$	0,029
12.Shoulder	34	0,0469			0,0469	$1,01^{a}$	0,062	$1,02^{a}$	0,062	$1,22^{b}$	0,062
13.Thin flank	42	0,0484	0,0145		0,5772	0,73	0,053	0,69	0,052	0,76	0,052
14.Fore shin	59	0,0013			0,0013	$0,97^{a}$	0,037	$0,91^{a}$	0,037	$1,14^{b}$	0,037
15.Hind shin	43	0,0146			0,0146	$0,88^{a}$	0,033	$0,90^{a}$	0,033	$1,03^{b}$	0,033
16.Carcass*	49	0,0290	0,0594		0,0970	0,99	0,046	0,95	0,041	1,08	0,042

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 40
Least Square Mean Values (± Standard Error of Mean) of Proline Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	40	0,0606	0,0470		0,2978	0,78	0,054	0,81	0,053	0,90	0,053
2.Loin	5	0,6672			0,6672	0,85	0,048	0,84	0,048	0,79	0,048
3.Wing rib	54	0,0114	0,0015		0,5073	0,85	0,049	0,83	0,048	0,77	0,048
4.Rump	44	0,0896	0,0118	0,0095	0,6898	0,82	0,064	0,83	0,036	0,76	0,063
5.Topside	1	0,9169			0,9169	0,79	0,029	0,78	0,029	0,80	0,029
6.Fillet	4	0,7246			0,7246	0,74	0,029	0,74	0,029	0,71	0,029
7.Silverside	47	0,0660	0,0674	0,0727	0,0597	0,80	0,038	0,91	0,038	0,94	0,038
8.Thick flank	3	0,8102			0,8102	0,91	0,035	0,88	0,028	0,90	0,028
9.Chuck	17	0,2497			0,2497	0,76	0,039	0,83	0,039	0,86	0,039
10.Brisket	50	0,0246	0,0235		0,2499	0,77	0,045	0,87	0,040	0,85	0,040
11.Neck	25	0,1161			0,1161	0,85	0,042	0,88	0,042	0,97	0,042
12.Shoulder	35	0,0390			0,0390	0,87^{a}	0,036	1,00^{b}	0,036	0,89^{a}	0,036
13.Thin flank	39	0,1471	0,0154	0,0184	0,9187	0,91	0,061	0,94	0,060	0,94	0,060
14.Fore Shin	22	0,3086	0,0858		0,9688	1,12	0,098	1,15	0,097	1,14	0,097
15.Hind Shin	4	0,7166			0,7166	1,15	0,090	1,24	0,090	1,25	0,090
16.Carcass*	25	0,1336			0,1336	0,79	0,039	0,89	0,035	0,89	0,035
COOKED (DRY HEAT)											
1.Prime rib	62	0,0029	0,0021		0,2035	1,11	0,039	1,20	0,038	1,21	0,039
2.Loin	75	0,0007	0,0028	0,0094	0,0691	1,22	0,054	1,42	0,053	1,36	0,054
3.Wing rib	73	0,0010	0,0236	0,0680	0,0279	1,13^{a}	0,035	1,19^{ab}	0,035	1,28^{b}	0,035
4.Rump	58	0,0161	0,0571	0,1359	0,4114	1,11	0,058	1,20	0,057	1,21	0,058
5.Topside	36	0,0943	0,0328		0,6891	1,21	0,044	1,20	0,043	1,25	0,044
6.Fillet	20	0,2054			0,2054	1,11	0,043	1,03	0,039	1,13	0,039
COOKED (MOIST HEAT)											
7.Silverside	50	0,0197	0,0479		0,1054	1,15	0,039	1,22	0,038	1,27	0,039
8.Thick flank	51	0,0407	0,0304	0,0404	0,1138	1,19	0,054	1,25	0,053	1,36	0,054
9.Chuck	83	0,0001	0,0028	0,0137	0,0131	1,09^{a}	0,033	1,23^{b}	0,033	1,24^{b}	0,033
10.Brisket	85	0,0001	0,0024	0,0169	0,0385	1,02^{a}	0,033	1,11^{ab}	0,032	1,16^{b}	0,033
11.Neck	86	0,0001	0,0001		0,0161	1,16^{a}	0,035	1,25^{ab}	0,035	1,33^{b}	0,035
12.Shoulder	53	0,0118	0,0781		0,0392	1,27^{a}	0,048	1,36^{ab}	0,047	1,46^{b}	0,048
13.Thin flank	72	0,0016	0,0039	0,0120	0,1321	1,14	0,059	1,07	0,058	1,25	0,059
14.Fore shin	49	0,0516	0,0932	0,1439	0,1457	1,50	0,067	1,64	0,066	1,69	0,067
15.Hind shin	51	0,0161	0,0416		0,0853	1,55	0,062	1,58	0,061	1,74	0,062
16.Carcass*	90	0,0001	0,0011	0,0094	0,0049	1,16^{a}	0,024	1,23^{b}	0,021	1,29^{c}	0,022

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly (p ≤ 0,05)

TABLE 41

Least Square Mean Values (± Standard Error of Mean) of Hydroxyproline Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	50	0,0178	0,0165		0,2027	0,22	0,030	0,26	0,029	0,30	0,029
2.Loin	3	0,7782			0,7782	0,26	0,032	0,28	0,032	0,25	0,032
3.Wing rib	43	0,0445	0,0155		0,2910	0,27	0,022	0,29	0,022	0,24	0,022
4.Rump	50	0,0499	0,0086	0,0074	0,4856	0,31	0,048	0,24	0,047	0,23	0,047
5.Topside	2	0,8876			0,8876	0,21	0,019	0,23	0,019	0,22	0,019
6.Fillet	22	0,1520			0,1520	0,09	0,013	0,12	0,013	0,11	0,013
7.Silverside	31	0,0628			0,0628	0,21	0,026	0,31	0,026	0,28	0,026
8.Thick flank	7	0,6124			0,6124	0,27	0,025	0,26	0,020	0,28	0,020
9.Chuck	29	0,0791			0,0791	0,20	0,019	0,23	0,019	0,27	0,019
10.Brisket	43	0,0193			0,0193	$0,28^{a}$	0,023	$0,35^{b}$	0,021	$0,38^{b}$	0,021
11.Neck	62	0,0029	0,0041		0,0674	0,32	0,020	0,34	0,020	0,39	0,020
12.Shoulder	35	0,0421			0,0421	$0,30^{a}$	0,031	$0,42^{b}$	0,031	$0,34^{ab}$	0,031
13.Thin flank	75	0,0007	0,0001	0,0002	0,1103	0,35	0,021	0,39	0,021	0,42	0,021
14.Fore Shin	34	0,1095	0,0230		0,8025	0,57	0,075	0,60	0,073	0,54	0,074
15.Hind Shin	2	0,8866			0,8866	0,67	0,089	0,70	0,089	0,73	0,089
16.Carcass*	37	0,1049	0,1432		0,2709	0,28	0,020	0,32	0,018	0,32	0,018
COOKED (DRY HEAT)											
1.Prime rib	61	0,0037	0,0125		0,0478	$0,32^{a}$	0,017	$0,34^{ab}$	0,017	$0,39^{b}$	0,017
2.Loin	61	0,0106	0,0402	0,0928	0,1959	0,36	0,038	0,44	0,038	0,46	0,038
3.Wing rib	65	0,0054	0,0063	0,0146	0,2032	0,37	0,023	0,40	0,023	0,44	0,023
4.Rump	59	0,0049	0,0007		0,7990	0,33	0,019	0,32	0,018	0,33	0,019
5.Topside	36	0,0899	0,0155		0,9809	0,33	0,017	0,33	0,016	0,33	0,017
6.Fillet	63	0,0120	0,0286	0,0781	0,5508	0,17	0,015	0,16	0,013	0,18	0,013
COOKED (MOIST HEAT)											
7.Silverside	68	0,0009	0,0084		0,0106	$0,30^{a}$	0,019	$0,33^{a}$	0,019	$0,39^{b}$	0,019
8.Thick flank	62	0,0100	0,0542	0,0870	0,0261	$0,33^{a}$	0,032	$0,39^{ab}$	0,031	$0,47^{b}$	0,032
9.Chuck	81	0,0001	0,0164	0,0519	0,0014	$0,26^{a}$	0,015	$0,36^{b}$	0,014	$0,34^{b}$	0,015
10.Brisket	79	0,0003	0,0026	0,0098	0,0413	$0,40^{a}$	0,025	$0,45^{ab}$	0,025	$0,50^{b}$	0,025
11.Neck	78	0,0001	0,0001		0,1259	0,42	0,023	0,47	0,023	0,49	0,023
12.Shoulder	60	0,0039	0,1376		0,0072	$0,43^{a}$	0,033	$0,48^{a}$	0,033	$0,60^{b}$	0,033
13.Thin flank	70	0,0022	0,0042	0,0093	0,0313	$0,49^{ab}$	0,035	$0,45^{a}$	0,034	$0,59^{b}$	0,035
14.Fore shin	38	0,0782	0,0714		0,3286	0,74	0,057	0,83	0,055	0,86	0,056
15.Hind shin	31	0,1470	0,0933		0,4246	0,88	0,074	0,84	0,073	0,98	0,074
16.Carcass*	89	0,0001	0,0028	0,0166	0,0016	$0,38^{a}$	0,014	$0,42^{a}$	0,012	$0,47^{b}$	0,013

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 42
Least Square Mean Values (± Standard Error of Mean) of Methionine For Beef Cuts Obtained From Three Age Groups (*n* = 18) (g/100g edible portion) (Fat of the carcass covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	35	0,1024	0,0409		0,6415	0,24	0,028	0,27	0,027	0,26	0,027
2.Loin	21	0,3231	0,1274		0,5278	0,30	0,034	0,32	0,033	0,27	0,033
3.Wing rib	40	0,0587	0,0435		0,1770	0,24	0,037	0,31	0,036	0,21	0,036
4.Rump	31	0,1421	0,0741		0,3078	0,27	0,033	0,30	0,033	0,23	0,033
5.Topside	39	0,0686	0,0286		0,2568	0,30	0,029	0,32	0,029	0,25	0,029
6.Fillet	10	0,4444			0,4444	0,31	0,037	0,37	0,037	0,30	0,037
7.Silverside	45	0,0342	0,0143		0,2599	0,29	0,033	0,34	0,032	0,26	0,032
8.Thick flank	53	0,0627	0,2524	0,1272	0,6157	0,29	0,040	0,33	0,032	0,29	0,032
9.Chuck	13	0,3637			0,3637	0,26	0,033	0,30	0,033	0,23	0,033
10.Brisket	35	0,1240	0,1468		0,2617	0,18	0,033	0,26	0,030	0,22	0,030
11.Neck	8	0,5544			0,5544	0,24	0,024	0,28	0,024	0,26	0,024
12.Shoulder	14	0,3161			0,3161	0,28	0,039	0,35	0,039	0,27	0,039
13.Thin flank	1	0,9481			0,9481	0,24	0,045	0,23	0,045	0,25	0,045
14.Fore Shin	50	0,0479	0,1860	0,1108	0,1975	0,26	0,028	0,33	0,027	0,29	0,027
15.Hind Shin	46	0,0324	0,0306		0,1194	0,25	0,026	0,31	0,026	0,23	0,026
16.Carcass*	35	0,1178	0,0751		0,3396	0,25	0,031	0,30	0,028	0,25	0,028
COOKED (DRY HEAT)											
1.Prime rib	58	0,0182	0,2949	0,1266	0,3497	0,35	0,038	0,43	0,037	0,39	0,038
2.Loin	67	0,0012	0,0069		0,0127	$0,35^a$	0,038	$0,54^b$	0,037	$0,48^b$	0,038
3.Wing rib	51	0,0409	0,1608	0,0812	0,2644	0,37	0,034	0,45	0,033	0,40	0,034
4.Rump	42	0,0515	0,0805		0,1926	0,36	0,043	0,44	0,042	0,48	0,043
5.Topside	22	0,3108	0,1464		0,7325	0,43	0,055	0,48	0,053	0,49	0,054
6.Fillet	34	0,2486	0,1513	0,1080	0,6456	0,44	0,046	0,50	0,041	0,47	0,041
COOKED (MOIST HEAT)											
7.Silverside	39	0,1441	0,2308	0,1427	0,5429	0,39	0,042	0,44	0,041	0,46	0,042
8.Thick flank	10	0,4619			0,4619	0,40	0,046	0,46	0,046	0,47	0,046
9.Chuck	70	0,0007	0,0003		0,1688	0,37	0,032	0,46	0,031	0,41	0,032
10.Brisket	65	0,0055	0,2787	0,1033	0,2277	0,27	0,025	0,34	0,024	0,32	0,025
11.Neck	59	0,0149	0,3338	0,1436	0,3529	0,33	0,044	0,42	0,043	0,40	0,043
12.Shoulder	49	0,0526	0,1747	0,1046	0,1736	0,43	0,046	0,55	0,045	0,54	0,046
13.Thin flank	54	0,0105	0,0081		0,2058	0,21	0,032	0,29	0,031	0,27	0,032
14.Fore shin	57	0,0070	0,0230		0,0314	$0,30^a$	0,027	$0,42^b$	0,027	$0,35^{ab}$	0,027
15.Hind shin	30	0,1587	0,1000		0,3943	0,33	0,043	0,42	0,043	0,37	0,043
16.Carcass*	63	0,0128	0,2195	0,0916	0,3764	0,36	0,036	0,43	0,031	0,42	0,032

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 43

Least Square Mean Values (± Standard Error of Mean) of Aspartic Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	6	0,6279			0,6279	1,36	0,092	1,44	0,092	1,49	0,092
2.Loin	4	0,7621			0,7621	1,54	0,075	1,59	0,075	1,51	0,075
3.Wing rib	56	0,0079	0,0021		0,3804	1,45	0,078	1,56	0,077	1,41	0,077
4.Rump	29	0,3233	0,0706	0,0693	0,4120	1,53	0,065	1,61	0,064	1,48	0,064
5.Topside	11	0,4342			0,4342	1,54	0,056	1,64	0,056	1,59	0,056
6.Fillet	27	0,2006	0,0912		0,4779	1,70	0,067	1,75	0,066	1,63	0,066
7.Silverside	42	0,0487	0,0846		0,1530	1,54	0,046	1,67	0,046	1,64	0,046
8.Thick flank	5	0,6974			0,6974	1,63	0,090	1,73	0,074	1,69	0,074
9.Chuck	25	0,2402	0,1162		0,5884	1,49	0,042	1,50	0,041	1,55	0,041
10.Brisket	71	0,0008	0,0011		0,0405	$1,25^{a}$	0,057	$1,46^{b}$	0,051	$1,31^{ab}$	0,051
11.Neck	29	0,0738			0,0738	1,43	0,045	1,51	0,045	1,58	0,045
12.Shoulder	39	0,0670	0,0314		0,3640	1,53	0,050	1,62	0,049	1,53	0,049
13.Thin flank	1	0,9498			0,9498	1,45	0,162	1,39	0,162	1,40	0,162
14.Fore Shin	12	0,3772			0,3772	1,57	0,096	1,73	0,096	1,75	0,096
15.Hind Shin	38	0,0265			0,0265	$1,44^{a}$	0,059	$1,69^{b}$	0,059	$1,60^{ab}$	0,059
16.Carcass*	43	0,0549	0,1438		0,1285	1,41	0,053	1,56	0,047	1,52	0,047
COOKED (DRY HEAT)											
1.Prime rib	74	0,0003	0,0004		0,0415	$1,97^{a}$	0,061	$2,13^{ab}$	0,060	$2,21^{b}$	0,061
2.Loin	74	0,0008	0,0378	0,1253	0,0215	$2,21^{a}$	0,084	$2,59^{b}$	0,082	$2,39^{ab}$	0,084
3.Wing rib	79	0,0001	0,0010		0,0012	$1,94^{a}$	0,047	$2,15^{b}$	0,046	$2,25^{b}$	0,047
4.Rump	55	0,0244	0,0549	0,1071	0,2092	2,13	0,121	2,39	0,119	2,43	0,121
5.Topside	12	0,3854			0,3854	2,37	0,110	2,40	0,110	2,57	0,110
6.Fillet	17	0,2747			0,2747	2,49	0,077	2,42	0,070	2,58	0,070
COOKED (MOIST HEAT)											
7.Silverside	15	0,3030			0,3030	2,25	0,085	2,38	0,085	2,44	0,085
8.Thick flank	30	0,2928	0,0951	0,0984	0,4129	2,37	0,093	2,43	0,091	2,55	0,093
9.Chuck	65	0,0059	0,0302	0,0797	0,1867	2,13	0,087	2,35	0,085	2,33	0,087
10.Brisket	68	0,0009	0,0005		0,2077	1,68	0,057	1,82	0,056	1,80	0,057
11.Neck	78	0,0001	0,0002		0,0138	$1,82^{a}$	0,085	$2,10^{b}$	0,084	$2,24^{b}$	0,085
12.Shoulder	54	0,0111	0,0860		0,0325	$2,18^{a}$	0,067	$2,40^{b}$	0,065	$2,45^{b}$	0,066
13.Thin flank	59	0,0153	0,0368	0,0968	0,7259	1,52	0,085	1,60	0,083	1,60	0,084
14.Fore shin	74	0,0010	0,0145	0,0156	0,0010	$2,17^{a}$	0,051	$2,39^{b}$	0,050	$2,53^{b}$	0,050
15.Hind shin	36	0,0341			0,0341	$2,04^{a}$	0,074	$2,20^{ab}$	0,074	$2,34^{b}$	0,074
16.Carcass*	68	0,0015	0,0021		0,1183	2,05	0,068	2,20	0,060	2,25	0,061

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 44

Least Square Mean Values (± Standard Error of Mean) of Phenylalanine Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SE
RAW											
1.Prime rib	12	0,3775			0,3775	0,58	0,042	0,61	0,042	0,67	0,042
2.Loin	4	0,7295			0,7295	0,63	0,038	0,66	0,038	0,62	0,038
3.Wing rib	52	0,0143	0,0033		0,5462	0,61	0,036	0,65	0,036	0,60	0,036
4.Rump	31	0,2693	0,0573	0,0508	0,3873	0,62	0,021	0,66	0,021	0,63	0,021
5.Topside	3	0,7733			0,7733	0,64	0,028	0,67	0,028	0,66	0,028
6.Fillet	4	0,7540			0,7540	0,72	0,038	0,70	0,038	0,68	0,038
7.Silverside	19	0,2047			0,2047	0,64	0,028	0,71	0,028	0,69	0,028
8.Thick flank	4	0,7818			0,7818	0,67	0,041	0,71	0,033	0,71	0,033
9.Chuck	25	0,2472	0,0591		0,9239	0,65	0,028	0,66	0,028	0,64	0,028
10.Brisket	67	0,0019	0,0024		0,0671	0,52	0,031	0,63	0,027	0,56	0,027
11.Neck	22	0,1534			0,1534	0,60	0,022	0,64	0,022	0,66	0,022
12.Shoulder	24	0,1229			0,1229	0,61	0,027	0,69	0,027	0,63	0,027
13.Thin flank	1	0,9588			0,9588	0,62	0,074	0,60	0,074	0,63	0,074
14.Fore Shin	12	0,3963			0,3963	0,65	0,042	0,70	0,042	0,73	0,042
15.Hind Shin	37	0,0304			0,0304	$0,58^{a}$	0,025	$0,68^{b}$	0,025	$0,65^{ab}$	0,025
16.Carcass*	33	0,0588			0,0588	0,57	0,027	0,66	0,025	0,64	0,025
COOKED (DRY HEAT)											
1.Prime rib	70	0,0007	0,0007		0,0941	$0,84^{a}$	0,032	$0,91^{ab}$	0,031	$0,95^{b}$	0,032
2.Loin	65	0,0057	0,0509	0,1195	0,0354	$0,93^{a}$	0,047	$1,12^{b}$	0,046	$0,99^{ab}$	0,047
3.Wing rib	64	0,0020	0,0165		0,0172	$0,81^{a}$	0,029	$0,90^{b}$	0,028	$0,95^{b}$	0,029
4.Rump	44	0,0405	0,0680		0,1670	0,88	0,058	1,01	0,057	1,03	0,058
5.Topside	13	0,3683			0,3683	0,97	0,054	1,00	0,054	1,08	0,054
6.Fillet	36	0,0425			0,0425	$1,05^{ab}$	0,030	$1,01^{a}$	0,027	$1,11^{b}$	0,027
COOKED (MOIST HEAT)											
7.Silverside	16	0,2612			0,2612	0,94	0,038	1,02	0,038	1,03	0,038
8.Thick flank	11	0,4170			0,4170	0,98	0,046	1,02	0,046	1,07	0,046
9.Chuck	62	0,0032	0,0045		0,1032	0,90	0,041	1,01	0,040	1,03	0,041
10.Brisket	65	0,0017	0,0009		0,2255	0,71	0,028	0,78	0,027	0,76	0,027
11.Neck	80	0,0001	0,0002		0,0033	$0,81^{a}$	0,028	$0,89^{a}$	0,027	$0,98^{b}$	0,027
12.Shoulder	26	0,1000			0,1000	0,92	0,049	1,02	0,049	1,07	0,049
13.Thin flank	58	0,0172	0,0123	0,0311	0,9415	0,69	0,037	0,69	0,036	0,70	0,037
14.Fore shin	59	0,0147	0,0952	0,1202	0,0146	$0,89^{a}$	0,030	$0,98^{ab}$	0,029	$1,04^{b}$	0,030
15.Hind shin	51	0,0051			0,0051	$0,82^{a}$	0,027	$0,92^{b}$	0,027	$0,97^{b}$	0,027
16.Carcass*	61	0,0052	0,0098		0,1127	0,86	0,034	0,93	0,030	0,96	0,031

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly (p ≤ 0,05)

TABLE 45

Least Square Mean Values (± Standard Error of Mean) of Glutamic Acid Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g /100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	21	0,3391	0,1445		0,7102	2,31	0,147	2,31	0,145	2,46	0,145
2.Loin	4	0,7300			0,7300	2,49	0,098	2,56	0,098	2,45	0,098
3.Wing rib	58	0,0060	0,0014		0,3414	2,39	0,132	2,56	0,130	2,28	0,130
4.Rump	34	0,2248	0,0318	0,0322	0,5608	2,51	0,108	2,56	0,107	2,40	0,107
5.Topside	6	0,6417			0,6417	2,50	0,084	2,59	0,084	2,60	0,084
6.Fillet	18	0,2362			0,2362	2,77	0,080	2,70	0,080	2,57	0,080
7.Silverside	46	0,0294	0,0249		0,2687	2,51	0,070	2,66	0,069	2,67	0,069
8.Thick flank	0,3	0,9834			0,9834	2,77	0,147	2,77	0,120	2,80	0,120
9.Chuck	28	0,1950	0,0573		0,7718	2,56	0,084	2,53	0,082	2,62	0,082
10.Brisket	74	0,0004	0,0004		0,0755	2,04	0,085	2,33	0,076	2,19	0,076
11.Neck	39	0,0250			0,0250	$2,38^{a}$	0,071	$2,45^{a}$	0,071	$2,68^{b}$	0,071
12.Shoulder	29	0,1772	0,0561		0,8337	2,54	0,078	2,60	0,077	2,60	0,077
13.Thin flank	3	0,7870			0,7870	2,39	0,262	2,17	0,262	2,39	0,262
14.Fore Shin	10	0,4751			0,4751	2,65	0,155	2,81	0,155	2,92	0,155
15.Hind Shin	30	0,0694			0,0694	2,40	0,097	2,72	0,097	2,68	0,097
16.Carcass*	60	0,0179	0,0389	0,0688	0,0621	2,29	0,073	2,53	0,065	2,52	0,064
COOKED (DRY HEAT)											
1.Prime rib	71	0,0004	0,0005		0,0912	3,26	0,107	3,48	0,105	3,63	0,107
2.Loin	84	0,0001	0,0004	0,0022	0,0145	$3,69^{a}$	0,098	$4,16^{b}$	0,096	$3,93^{ab}$	0,098
3.Wing rib	77	0,0001	0,0007		0,0050	$3,18^{a}$	0,083	$3,48^{b}$	0,081	$3,65^{b}$	0,083
4.Rump	57	0,0200	0,0320	0,0638	0,2276	3,46	0,200	3,81	0,196	3,97	0,200
5.Topside	52	0,0134	0,0151		0,1261	3,88	0,134	3,75	0,131	4,15	0,134
6.Fillet	55	0,0350	0,0534	0,0704	0,0376	$4,15^{ab}$	0,101	$3,88^{a}$	0,090	$4,24^{b}$	0,092
COOKED (MOIST HEAT)											
7.Silverside	42	0,1041	0,0678	0,0983	0,3165	3,67	0,120	3,84	0,118	3,94	0,120
8.Thick flank	47	0,0627	0,0330	0,0340	0,1048	3,90	0,124	3,81	0,122	4,20	0,124
9.Chuck	74	0,0009	0,0094	0,0346	0,1409	3,58	0,128	3,87	0,125	3,96	0,127
10.Brisket	81	0,0001	0,0106	0,0600	0,0737	2,74	0,073	2,97	0,071	2,96	0,073
11.Neck	84	0,0001	0,0001		0,0024	$3,21^{a}$	0,092	$3,45^{a}$	0,090	$3,78^{b}$	0,092
12.Shoulder	60	0,0043	0,0122		0,0587	3,67	0,087	3,91	0,086	3,99	0,087
13.Thin flank	63	0,0085	0,0232	0,0677	0,7099	2,48	0,134	2,61	0,131	2,63	0,134
14.Fore shin	63	0,0075	0,0106	0,0156	0,0328	$3,67^{a}$	0,103	$3,89^{ab}$	0,101	$4,12^{b}$	0,103
15.Hind shin	60	0,0010			0,0010	$3,36^{a}$	0,077	$3,60^{b}$	0,077	$3,88^{c}$	0,077
16.Carcass*	86	0,0001	0,0018	0,0096	0,0160	$3,36^{a}$	0,074	$3,57^{ab}$	0,066	$3,71^{b}$	0,067

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 46

Least Square Mean Values (± Standard Error of Mean) of Lysine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	40	0,0591	0,0513		0,2192	1,57	0,139	1,91	0,136	1,63	0,137
2.Loin	51	0,0047			0,0047	$1,61^{a}$	0,104	$2,14^{b}$	0,104	$1,67^{a}$	0,104
3.Wing rib	71	0,0005	0,0013		0,0108	$1,55^{a}$	0,107	$2,03^{b}$	0,105	1,59	$0,105^{a}$
4,Rump	40	0,0217			0,0217	$1,48^{a}$	0,102	$1,94^{b}$	0,102	$1,71^{ab}$	0,102
5.Topside	50	0,0197	0,1379		0,0266	$1,57^{a}$	0,099	$1,97^{b}$	0,097	$1,64^{a}$	0,097
6.Fillet	13	0,3394			0,3394	1,65	0,117	1,89	0,117	1,70	0,117
7.Silverside	49	0,0218	0,1226		0,0336	$1,62^{a}$	0,108	$2,04^{b}$	0,106	$1,71^{a}$	0,107
8.Thick flank	25	0,1605			0,1605	1,78	0,120	2,02	0,098	1,76	0,098
9.Chuck	24	0,1240			0,1240	1,67	0,121	2,04	0,121	1,83	0,121
10.Brisket	68	0,0016	0,0145		0,0086	$1,36^{a}$	0,118	$1,93^{b}$	0,105	$1,56^{a}$	0,106
11.Neck	52	0,0044			0,0044	$1,52^{a}$	0,091	$2,03^{b}$	0,091	$1,77^{ab}$	0,091
12.Shoulder	34	0,0430			0,0430	$1,59^{a}$	0,120	$2,05^{b}$	0,120	$1,73^{ab}$	0,120
13.Thin flank	6	0,6250			0,6250	1,52	0,202	1,80	0,202	1,68	0,202
14.Fore Shin	25	0,1129			0,1129	1,61	0,148	2,07	0,148	1,78	0,148
15.Hind Shin	67	0,0012	0,0677		0,0020	1,53	0,092	2,11	0,091	1,75	0,091
16.Carcass*	62	0,0049	0,1356		0,0077	$1,45^{a}$	0,104	$1,98^{b}$	0,093	$1,69^{a}$	0,093
COOKED (DRY HEAT)											
1.Prime rib	65	0,0018	0,0058		0,0128	$2,17^{a}$	0,157	$2,91^{b}$	0,154	$2,38^{a}$	0,156
2.Loin	70	0,0007	0,0118		0,0017	$2,36^{a}$	0,159	$3,31^{b}$	0,155	$2,56^{a}$	0,158
3.Wing rib	58	0,0054	0,0467		0,0180	$2,05^{a}$	0,143	$2,69^{b}$	0,140	$2,53^{b}$	0,143
4.Rump	35	0,0380			0,0380	$2,22^{a}$	0,215	$3,03^{b}$	0,215	$2,90^{b}$	0,215
5.Topside	50	0,0189	0,0388		0,0966	2,35	0,167	2,88	0,163	2,77	0,166
6.Fillet	37	0,1007	0,0744		0,2880	2,65	0,156	2,98	0,139	2,75	0,141
COOKED (MOIST HEAT)											
7.Silverside	63	0,0024	0,0868		0,0037	$2,31^{a}$	0,115	$2,98^{b}$	0,112	$2,67^{b}$	0,114
8.Thick flank	54	0,0100	0,0405		0,0364	$2,43^{a}$	0,132	$2,96^{b}$	0,130	$2,79^{ab}$	0,132
9.Chuck	67	0,0012	0,0039		0,0109	$2,34^{a}$	0,148	$3,05^{b}$	0,145	$2,54^{a}$	0,148
10 Brisket	67	0,0012	0,0020		0,0281	$1,83^{a}$	0,111	$2,30^{b}$	0,108	$2,02^{ab}$	0,110
11.Neck	85	0,0001	0,4997	0,1377	0,0008	$2,09^{a}$	0,094	$2,75^{b}$	0,092	$2,53^{b}$	0,093
12.Shoulder	55	0,0089	0,0337		0,0252	$2,20^{a}$	0,205	$3,06^{b}$	0,201	$2,46^{ab}$	0,205
13.Thin flank	72	0,0004	0,0003		0,0464	$1,61^{a}$	0,105	$2,02^{b}$	0,103	$1,80^{ab}$	0,105
14.Fore shin	59	0,0138	0,0409	0,0616	0,0197	$2,26^{a}$	0,119	$2,80^{b}$	0,117	$2,48^{ab}$	0,119
15.Hind shin	66	0,0013	0,0726		0,0018	$2,03^{a}$	0,109	$2,72^{b}$	0,107	$2,37^{c}$	0,109
16.Carcass*	75	0,0003	0,0029		0,0036	$2,10^{a}$	0,120	$2,78^{b}$	0,107	$2,45^{b}$	0,109

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 47

Least Square Mean Values (± Standard Error of Mean) of Tyrosine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	17	0,2551			0,2551	0,51	0,044	0,47	0,044	0,58	0,044
2.Loin	14	0,3221			0,3221	0,50	0,041	0,56	0,041	0,47	0,041
3.Wing rib	41	0,0566	0,0604		0,1142	0,51	0,036	0,58	0,036	0,46	0,036
4.Rump	3	0,8249			0,8249	0,49	0,040	0,51	0,040	0,47	0,040
5.Topside	10	0,4422			0,4422	0,46	0,040	0,52	0,040	0,45	0,040
6.Fillet	15	0,2850			0,2580	0,51	0,047	0,58	0,047	0,47	0,047
7.Silverside	20	0,1968			0,1968	0,48	0,037	0,55	0,037	0,45	0,037
8.Thick flank	14	0,3766			0,3766	0,50	0,050	0,56	0,041	0,47	0,041
9.Chuck	2	0,8921			0,8921	0,58	0,050	0,55	0,050	0.57	0,050
10.Brisket	5	0,6821			0,6821	0,41	0,048	0,44	0,044	0,47	0,044
11.Neck	1	0,9436			0,9436	0,54	0,049	0,53	0,049	0,55	0,049
12.Shoulder	4	0,7496			0,7496	0,57	0,041	0,54	0,041	0,53	0,041
13.Thin flank	1	0,9121			0,9121	0,51	0,050	0,48	0,050	0,50	0,050
14.Fore Shin	15	0,3029			0,3029	0,43	0,052	0,55	0,052	0,47	0,052
15.Hind Shin	2	0,8424			0,8424	0,52	0,030	0,50	0,030	0,52	0,030
16.Carcass*	4	0,7534			0,7534	0,48	0,034	0,52	0,031	0,50	0,031
COOKED (DRY HEAT)											
1.Prime rib	13	0,3571			0,3571	0,75	0,058	0,86	0,058	0,75	0,058
2.Loin	22	0,1580			0,1580	0,80	0,049	0,90	0,048	0,77	0,049
3.Wing rib	46	0,0704	0,2483	0,1374	0,3223	0,67	0,050	0,78	0,049	0,72	0,050
4.Rump	19	0,3812	0,1203		0,7779	0,74	0,068	0,78	0,067	0,72	0,068
5.Topside	8	0,5543			0,5543	0,77	0,052	0,81	0,052	0,73	0,052
6.Fillet	2	0,8530			0,8530	0,80	0,057	0,77	0,052	0,81	0,052
COOKED (MOIST HEAT)											
7.Silverside	23	0,1401			0,1401	0,77	0,037	0,79	0,037	0,69	0,037
8.Thick flank	10	0,4531			0,4531	0,81	0,042	0,79	0,042	0,73	0,042
9.Chuck	42	0,0495	0,0155		0,6893	0,80	0,055	0,87	0,054	0,85	0,055
10.Brisket	22	0,3094	0,0757		0,9995	0,62	0,038	0,62	0,037	0,62	0,038
11.Neck	36	0,0903	0,0853		0,3341	0,70	0,053	0,78	0,052	0,82	0,053
12.Shoulder	3	0,8062			0,8062	0,86	0,069	0,86	0,069	0,92	0,069
13.Thin flank	30	0,1673	0,0385		0,5252	0,58	0,045	0,59	0,044	0,52	0,045
14.Fore shin	1	0,9200			0,9200	0,79	0,114	0,78	0,114	0,73	0,114
15.Hind shin	3	0,7712			0,7712	0,73	0,040	0,77	0,040	0,76	0,040
16.Carcass*	24	0,2994	0,0783		0,8011	0,76	0,043	0,77	0,038	0,73	0,039

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

abc Means in the same row with different superscripts differ significantly (p ≤ 0,05)

TABLE 48

Least Square Mean Values (± Standard Error of Mean) of Arginine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^{2} %	p-Value	X p-Value	X^{2} p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	45	0,0342	0,0178		0,2557	1,08	0,047	1,04	0,046	1,15	0,046
2.Loin	9	0,4759			0,4759	1,18	0,052	1,16	0,052	1,09	0,052
3.Wing rib	51	0,0155	0,0022		0,7977	1,11	0,056	1,12	0,055	1,07	0,055
4.Rump	42	0,1121	0,0182	0,0149	0,5221	1,16	0,059	1,17	0,058	1,08	0,058
5.Topside	10	0,4720			0,4720	1,18	0,029	1,13	0,029	1,15	0,029
6.Fillet	6	0,6249			0,6249	1,30	0,053	1,26	0,053	1,22	0,053
7.Silverside	13	0,3395			0,3395	1,17	0,030	1,21	0,030	1,23	0,030
8.Thick flank	13	0,4139			0,4139	1,29	0,050	1,23	0,041	1,31	0,041
9.Chuck	11	0,4194			0,4191	1,15	0,042	1,14	0,042	1,21	0,042
10.Brisket	58	0,0086	0,0036		0,4247	1,01	0,048	1,09	0,043	1,05	0,043
11.Neck	35	0,0393			0,0393	1,13^{a}	0,039	1,13^{a}	0,039	1,26^{b}	0,039
12.Shoulder	7	0,5822			0,5822	1,20	0,034	1,25	0,034	1,22	0,034
13.Thin flank	6	0,6254			0,6254	1,17	0,109	1,03	0,109	1,15	0,109
14.Fore Shin	5	0,6572			0,6572	1,32	0,085	1,38	0,085	1,43	0,085
15.Hind Shin	15	0,2877			0,2877	1,27	0,066	1,41	0,066	1,39	0,066
16.Carcass*	21	0,1904			0,1904	1,09	0,037	1,16	0,034	1,19	0,034
COOKED (DRY HEAT)											
1.Prime rib	65	0,0017	0,0010		0,2337	1,51	0,056	1,55	0,054	1,65	0,055
2.Loin	85	0,0001	0,0012	0,0080	0,0581	1,71	0,038	1,84	0,038	1,81	0,038
3.Wing rib	79	0,0001	0,0002		0,0077	1,51^{a}	0,038	1,54^{a}	0,037	1,70^{b}	0,038
4.Rump	73	0,0003	0,0003		0,0502	1,64^{a}	0,057	1,61^{a}	0,056	1,82^{b}	0,057
5.Topside	46	0,0315	0,0878		0,0573	1,79	0,046	1,69	0,045	1,86	0,046
6.Fillet	34	0,0574			0,0574	1,87	0,049	1,76	0,045	1,92	0,045
COOKED (MOIST HEAT)											
7.Silverside	50	0,0187	0,0509		0,0772	1,72	0,043	1,71	0,042	1,85	0,043
8.Thick flank	37	0,0311			0,0311	1,82^{ab}	0,046	1,75^{a}	0,046	1,94^{b}	0,046
9.Chuck	68	0,0034	0,0250	0,0761	0,2606	1,65	0,060	1,69	0,058	1,79	0,059
10.Brisket	81	0,0001	0,0160	0,0932	0,1199	1,35	0,037	1,37	0,036	1,46	0,037
11.Neck	77	0,0001	0,0003		0,0118	1,53^{a}	0,047	1,58^{a}	0,046	1,75^{b}	0,047
12.Shoulder	36	0,0350			0,0350	1,74^{a}	0,070	1,80^{a}	0,070	2,01^{b}	0,070
13.Thin flank	66	0,0050	0,0418	0,1335	0,4394	1,25	0,060	1,20	0,058	1,31	0,059
14.Fore shin	41	0,0203			0,0203	1,84^{a}	0,054	1,91^{a}	0,054	2,08^{b}	0,054
15.Hind shin	49	0,0515	0,1657	0,1320	0,0451	1,80^{a}	0,042	1,82^{a}	0,041	1,95^{b}	0,042
16.Carcass*	83	0,0001	0,0001		0,0069	1,59^{a}	0,034	1,61^{a}	0,030	1,75^{b}	0,030

[1] p-values are of the full model, if not significant ($p \geq 0{,}15$) the covariant was removed from the model starting with X^{2} and continuing with X,

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0{,}05$)

TABLE 49

Least Square Mean Values (± Standard Error of Mean) of Histidine Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	13	0,3677			0,3677	0,50	0,056	0,56	0,056	0,62	0,056
2.Loin	11	0,4223			0,4223	0,56	0,041	0,63	0,041	0,62	0,041
3.Wing rib	33	0,1258	0,0951		0,3294	0,52	0,061	0,65	0,059	0,56	0,060
4.Rump	31	0,0603			0,0603	0,49	0,029	0,55	0,029	0,60	0,029
5.Topside	12	0,3876			0,3876	0,52	0,058	0,63	0,058	0,60	0,058
6.Fillet	4	0,7572			0,7572	0,55	0,048	0,59	0,048	0,60	0,048
7.Silverside	8	0,5413			0,5413	0,56	0,043	0,63	0,043	0,60	0,043
8.Thick flank	9	0,5447			0,5447	0,55	0,067	0,64	0,055	0,64	0,055
9.Chuck	14	0,3185			0,3185	0,50	0,042	0,55	0,042	0,59	0,042
10.Brisket	33	0,1404	0,0974		0,3597	0,46	0,065	0,57	0,058	0,47	0,058
11.Neck	15	0,2862			0,2862	0,47	0,038	0,56	0,038	0,53	0,038
12.Shoulder	39	0,0707	0,0857		0,1140	0,52	0,044	0,60	0,043	0,47	0,043
13.Thin flank	1	0,9071			0,9071	0,53	0,091	0,56	0,091	0,51	0,091
14.Fore Shin	18	0,2349			0,2349	0,47	0,049	0,58	0,049	0,56	0,049
15.Hind Shin	38	0,0763	0,0953		0,1929	0,46	0,037	0,56	0,036	0,50	0,036
16.Carcass*	22	0,1802			0,1802	0,47	0,045	0,59	0,041	0,55	0,041
COOKED (DRY HEAT)											
1.Prime rib	36	0,0945	0,1392		0,1969	0,65	0,055	0,63	0,054	0,76	0,055
2.Loin	13	0,3511			0,3511	0,73	0,056	0,83	0,054	0,80	0,055
3.Wing rib	33	0,0520			0,0520	$0,68^{ab}$	0,038	$0,63^{a}$	0,038	$0,77^{b}$	0,038
4.Rump	25	0,1177			0,1177	0,70	0,061	0,74	0,061	0,88	0,061
5.Topside	23	0,1350			0,1350	0,74	0,055	0,80	0,055	0,91	0,055
6.Fillet	6	0,6419			0,6419	0,77	0,068	0,83	0,062	0,86	0,062
COOKED (MOIST HEAT)											
7.Silverside	27	0,0939			0,0939	0,72	0,045	0,75	0,045	0,86	0,045
8.Thick flank	27	0,3660	0,1124	0,0973	0,4961	0,71	0,048	0,75	0,047	0,79	0,048
9.Chuck	38	0,0270			0,0270	$0,63^{a}$	0,040	$0,75^{b}$	0,040	$0,80^{b}$	0,040
10.Brisket	29	0,1764	0,1182		0,5054	0,54	0,052	0,59	0,051	0,62	0,052
11.Neck	43	0,0417	0,1385		0,0792	0,61	0,048	0,58	0,047	0,74	0,048
12.Shoulder	31	0,0632			0,0632	0,64	0,048	0,72	0,048	0,82	0,048
13.Thin flank	12	0,3927			0,3927	0,51	0,072	0,60	0,072	0,65	0,072
14.Fore shin	42	0,1110	0,0936	0,0830	0,0986	0,62	0,038	0,68	0,038	0,75	0,038
15.Hind shin	32	0,0579			0,0579	0,55	0,041	0,55	0,041	0,68	0,041
16.Carcass*	31	0,0770			0,0770	0,63	0,045	0,69	0,041	0,78	0,041

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly (p ≤ 0,05)

TABLE 50

Least Square Mean Values (± Standard Error of Mean) of Tryptophan Content for Beef Cuts Obtained from Three Age Groups (n = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT1		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	40	0,0580	0,0414		0,1929	0,17	0,013	0,15	0,013	0,19	0,013
2.Loin	29	0,3148	0,2091	0,1351	0,9970	0,19	0,014	0,19	0,013	0,19	0,013
3.Wing rib	68	0,0009	0,0001		0,7999	0,18	0,010	0,18	0,010	0,17	0,010
4.Rump	59	0,0144	0,2555	0,1266	0,1311	0,17	0,008	0,20	0,008	0,19	0,008
5.Topside	48	0,0579	0,1143	0,0580	0,6922	0,19	0,009	0,20	0,009	0,20	0,009
6.Fillet	3	0,7893			0,7893	0,22	0,018	0,21	0,018	0,20	0,018
7.Silverside	69	0,0029	0,0174	0,0074	0,0851	0,18	0,008	0,21	0,007	0,20	0,007
8.Thick flank	12	0,4275			0,4275	0,18	0,015	0,20	0,012	0,21	0,012
9.Chuck	52	0,0359	0,1914	0,0892	0,4992	0,17	0,012	0,18	0,011	0,19	0,011
10.Brisket	48	0,0340	0,0066		0,9344	0,15	0,012	0,15	0,011	0,16	0,011
11.Neck	61	0,0108	0,0422	0,0233	0,0266	0,16	0,010	0,16	0,010	0,19	0,010
12.Shoulder	45	0,0340	0,0095		0,7403	0,18	0,010	0,19	0,010	0,20	0,010
13.Thin flank	14	0,3254			0,3254	0,19	0,027	0,13	0,027	0,15	0,027
14.Fore Shin	41	0,0187			0,0187	$0,15^{a}$	0,009	$0,18^{b}$	0,009	$0,20^{b}$	0,009
15.Hind Shin	72	0,0004	0,0033		0,0079	0,15	0,007	0,18	0,007	0,18	0,007
16.Carcass*	50	0,0249	0,0164		0,3767	0,17	0,009	0,18	0,008	0,18	0,008
COOKED (DRY HEAT)											
1.Prime rib	84	0,0001	0,0905	0,0118	0,1317	0,24	0,009	0,25	0,009	0,27	0,009
2.Loin	64	0,0019	0,0022		0,0587	0,27	0,015	0,32	0,015	0,29	0,015
3.Wing rib	83	0,0001	0,0176	0,0029	0,0808	0,24	0,010	0,25	0,010	0,27	0,010
4.Rump	25	0,2427	0,0829		0,8355	0,29	0,025	0,29	0,025	0,31	0,025
5.Topside	49	0,0522	0,0924	0,0476	0,5032	0,30	0,017	0,31	0,017	0,33	0,017
6.Fillet	56	0,0337	0,0727	0,0357	0,5412	0,30	0,016	0,31	0,014	0,32	0,014
COOKED (MOIST HEAT)											
7.Silverside	48	0,0619	0,0921	0,0505	0,4554	0,28	0,016	0,30	0,016	0,31	0,016
8.Thick flank	47	0,0625	0,1637	0,0882	0,4345	0,28	0,014	0,30	0,014	0,31	0,014
9.Chuck	80	0,0002	0,3106	0,0735	0,0603	0,26	0,011	0,29	0,011	0,30	0,011
10.Brisket	69	0,0007	0,0002		0,7532	0,18	0,010	0,19	0,010	0,20	0,010
11.Neck	80	0,0002	0,2210	0,0525	0,0253	$0,23^{a}$	0,011	$0,24^{a}$	0,011	$0,28^{b}$	0,011
12.Shoulder	64	0,0073	0,1995	0,0764	0,2626	0,28	0,013	0,29	0,012	0,31	0,012
13.Thin flank	42	0,0464	0,0099		0,9347	0,15	0,014	0,15	0,014	0,16	0,014
14.Fore shin	55	0,0249	0,2471	0,1417	0,0930	0,24	0,013	0,26	0,013	0,28	0,013
15.Hind shin	31	0,0596			0,0596	0,22	0,013	0,24	0,013	0,26	0,013
16.Carcass*	74	0,0016	0,2211	0,0681	0,2104	0,24	0,012	0,26	0,011	0,27	0,011

[1] p-values are of the full model, if not significant ($p \geq 0,15$) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly ($p \leq 0,05$)

TABLE 51

Least Square Mean Values (± Standard Error of Mean) of Cystine Content for Beef Cuts Obtained from Three Age Groups (*n* = 18) (g/100 g edible portion) (Fat of the Carcass Covariant = 16,51%)

CUT	MODEL		CO-VARIANT[1]		AGE						
	R^2 %	p-Value	X p-Value	X^2 p-Value	Age p-Value	A		B		C	
						Mean	SEM	Mean	SEM	Mean	SEM
RAW											
1.Prime rib	7	0,6009			0,6009	0,21	0,014	0,20	0,014	0,22	0,014
2.Loin	23	0,1414			0,1414	0,22	0,006	0,20	0,006	0,21	0,006
3.Wing rib	25	0,2412	0,0812		0,3551	0,23	0,016	0,21	0,015	0,20	0,015
4.Rump	36	0,1812	0,0691	0,0832	0,2253	0,22	0,010	0,21	0,010	0,20	0,010
5.Topside	24	0,2696	0,1410		0,2636	0,23	0,009	0,21	0,009	0,21	0,009
6.Fillet	29	0,0784			0,0784	0,24	0,007	0,22	0,007	0,23	0,007
7.Silverside	39	0,0706	0,0109		0,6905	0,23	0,009	0,22	0,009	0,22	0,009
8.Thick flank	8	0,5640			0,5640	0,24	0,012	0,22	0,010	0,23	0,010
9.Chuck	16	0,2727			0,2727	0,22	0,006	0,21	0,006	0,23	0,006
10.Brisket	47	0,0362	0,0072		0,6267	0,20	0,011	0,20	0,009	0,19	0,009
11.Neck	24	0,1316			0,1316	0,21	0,009	0,21	0,009	0,24	0,009
12.Shoulder	25	0,2481	0,0514		0,7472	0,21	0,009	0,21	0,008	0,21	0,008
13.Thin flank	70	0,0005	0,0001		0,2165	0,20	0,007	0,18	0,006	0,18	0,006
14.Fore Shin	54	0,0280	0,0079	0,0127	0,3188	0,23	0,008	0,22	0,008	0,24	0,008
15.Hind Shin	22	0,1596			0,1596	0,19	0,011	0,21	0,011	0,22	0,011
16.Carcass*	52	0,0530	0,0262	0,0477	0,4657	0,20	0,007	0,21	0,006	0,21	0,006
COOKED (DRY HEAT)											
1.Prime rib	54	0,0107	0,0019		0,9458	0,29	0,012	0,29	0,012	0,29	0,012
2.Loin	66	0,0047	0,0397	0,1450	0,9052	0,31	0,011	0,30	0,010	0,30	0,011
3.Wing rib	60	0,0043	0,0056		0,0595	0,28	0,010	0,26	0,010	0,30	0,010
4.Rump	70	0,0005	0,0001		0,4279	0,29	0,012	0,28	0,011	0,30	0,011
5.Topside	36	0,0897	0,0797		0,1792	0,32	0,012	0,30	0,011	0,32	0,012
6.Fillet	46	0,0135			0,0135	0,33^{ab}	0,011	0,30^{a}	0,010	0,35^{b}	0,010
COOKED (MOIST HEAT)											
7.Silverside	30	0,1677	0,0921		0,5837	0,30	0,011	0,31	0,010	0,31	0,011
8.Thick flank	8	0,5271			0,5271	0,32	0,010	0,32	0,010	0,33	0,010
9.Chuck	65	0,0055	0,0040	0,0111	0,6166	0,33	0,012	0,32	0,012	0,33	0,012
10.Brisket	74	0,0009	0,0049	0,0226	0,1072	0,25	0,008	0,23	0,008	0,24	0,008
11.Neck	80	0,0001	0,0001		0,0742	0,28	0,008	0,29	0,008	0,31	0,008
12.Shoulder	23	0,2938	0,1161		0,7784	0,30	0,012	0,30	0,012	0,31	0,012
13.Thin flank	71	0,0016	0,0022	0,0089	0,2879	0,23	0,010	0,21	0,009	0,21	0,010
14.Fore shin	72	0,0015	0,1365	0,1456	0,0006	0,29^{a}	0,007	0,30^{a}	0,007	0,34^{b}	0,007
15.Hind shin	24	0,1264			0,1264	0,27	0,008	0,28	0,008	0,29	0,008
16.Carcass*	80	0,0004	0,0044	0,0213	0,2514	0,28	0,007	0,28	0,006	0,30	0,006

[1] p-values are of the full model, if not significant (p ≥ 0,15) the covariant was removed from the model starting with X^2 and continuing with X

* Calculated

[abc] Means in the same row with different superscripts differ significantly (p ≤ 0,05)

Annexure C

Forward Stepwise Regression Analysis for Predition

TABLE 1
Forward Stepwise Regression Analysis For The Prediction Of Tenderness For The Three Age Groups Without Sensory Evaluation Scores

Muscle	Attribute[1]	R^2	p-Value	Regression Coefficient	Standard error of Obsrevation
LTP[2]	Constant			-0,58	4,37
	Instron	62,4	0,001	-0,02	0,002
	Age	68,1	0,001	-0,07	0,02
	KWTsubf	71,0	0,001	0,01	0,002
	Cmusl	72,4	0,001	0,11	0,06
LL	Constant			8,93	1,01
	Instron	39,0	0,001	-0,04	0,006
	Cbone	42,9	0,001	-0,13	0,06
LTW	Constant			8,19	0,30
	Instron	73,0	0,001	-0,03	0,003
ST	Constant			9,95	0,42
	Instron	72,6	0,001	-0,04	0,004
	Age	73,8	0,001	-0,04	0,02
GM	Constant			10,02	1,01
	Cbone	26,0	0,001	-0,27	0,05
	Instron	48,3	0,001	-0,02	0,004
	Rprot	50,6	0,001	0,09	0,05
SM	Constant			7,01	0,45
	Age	20,6	0,001	-0,10	0,02
	Instron	38,2	0,001	-0,01	0,003
PM	Constant			9,32	0,50
	Instron	20,8	0,001	-0,03	0,005
	Age	36,6	0,001	-0,09	0,02
	LNCsubf	42,9	0,001	-0,30	0,14
GB	Constant			-229,0	109
	Instron	57,8	0,001	-0,02	0,003
	Age	62,2	0,001	-0,11	0,03
	LNTsubf	66,0	0,001	-0,10	0,29
	SQCfatcr	68,2	0,001	-1,16	0,31
	Csubf	70,6	0,001	-0,30	0,107
	Tmeat	72,5	0,001	2,39	1,09
VL	Constant			7,62	0,26
	Instron	63,5	0,001	-0,21	0,03
	Age	67,0	0,001	-0,05	0,02
SV	Constant			8,86	0,45
	Instron	60,0	0,001	-0,04	0,004
	Age	73,0	0,001	-0,12	0,02
	Tbone	75,5	0,001	-0,07	0,03
PP	Constant			6,13	0,45
	Age	40,0	0,001	-0,16	0,04
	Instron	55,4	0,001	-0,36	0,10
BC	Constant			13,46	1,87
	Age	28,9	0,001	-0,11	0,04
	Rprot	44,8	0,001	-0,28	0,08
TBCL	Constant			21,89	5,44
	Age	30,4	0,001	-0,05	0,04
	Tbone	38,9	0,001	-0,58	0,15
	LNSEfat	44,5	0,001	-0,79	0,25
	Cmusl	49,7	0,001	-0,14	0,06
OAE	Constant			6,69	0,46
	Instron	25,4	0,001	-0,01	0,005
	Age	30,6	0,001	-0,09	0,05
ECR	Constant			6,70	0,91
	Age	39,5	0,001	-0,11	0,03
	Cbone	47,8	0,001	-0,13	0,06
	Instron	50,5	0,001	-0,01	0,005
FDM	Constant			6,70	0,91
	Age			-0,11	0,03
	Cbone			-0,13	0,06
	Instron			-0,01	0,005

[1] *Carcass parameters (%):* Cfatcr - Proximate fat content of carcass; Csubf - Subcutaneous fat of carcass; Cmusl - Muscle content of carcass; Cbone - Bone content of carcass; Cmeat - Meat contant (Csubf and Cmusl) of carcass;
Cut parameters (%): Rfat - Proximate fat content of cut; Rprot - Protein content of cut; Rmoist - Moisture content of cut; Tsubf - Subcutaneous fat of cut; Tmusl - Muscle content of cut; Tbone - Bone content of cut; Tmeat - Meat content (Tsubf and Tmusl) of cut; SEfat - Proximate fat in cooked muscle; *Transformations:* LN - Log X; SQ -$\sqrt{x}$; KW – X^2; TR – X^3

[2] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

TABLE 2
Forward Stepwise Regression Analysis For The Prediction Of Tenderness For The A Age Group Without Sensory Evaluation Scores

Muscle	Attribute[1]	R^2	p-Value	Regression Coefficient	Standard error of Obsrevation
LTP[2]	Constant Instron	 75,7	 0,001	7,82 -0,02	0,47 0,003
LL	Constant Instron	 18,1	 0,031	5,87 -0,02	0,48 0,008
LTW	Constant Instron Rprot	 66.8 76,4	 0,001 0,001	12,15 -0,03 0,21	1,52 0,005 0,08
ST	Constant Instron	 60,2	 0,001	10,87 -0,06	0,92 0,01
GM	Constant Tbone	 18,9	 0,032	7,97 -0,14	1,06 0,06
SM	Constant Tmeat	 30,9	 0,005	-18,86 0,26	7,67 0,08
PM	Constant Instron LNCfatcr Rmoist TRRfat	 42,5 62,7 78,7 82,0	 0,001 0,001 0,001 0,001	24,51 -0,04 -1,27 -0,16 -0,0002	3,41 0,004 0,19 0,04 0,0001
GB	Constant Cmeat	 40,5	 0,001	-25,32 0,37	8,08 0,10
VL	Constant Instron LNRFat	 31,3 44,8	 0,005 0,005	6,52 -0,17 0,48	0,76 0,07 0,20
SV	Constant Instron SQSEfat Rprot	 60,6 70,8 77,5	 0,001 0,001 0,001	0,96 0,03 0,94 0,22	2,49 0,005 0,27 0,10
PP	Constant			4,64	0,22
BC	Constant Rprot LNCsubf	 41,6 54,3	 0,004 0,001	13,21 -0,33 -0,87	1,79 0,09 0,39
TBCL	Constant Instron Tmeat	 27,4 63,9	 0,026 0,001	-51,6 -0,02 0,64	15,6 0,005 0,17
OAE	Constant Tmeat TRCFatcr	 42,1 57,2	 0,018 0,014	190,7 -1,80 0,0002	29,7 0,31 0,00004
ECR	Constant			4,15	0,21
FDM	Constant			4,15	0,21

[1] *Carcass parameters (%):* Cfatcr - Proximate fat content of carcass; Csubf - Subcutaneous fat of carcass; Cmusl - Muscle content of carcass; Cbone - Bone content of carcass; Cmeat - Meat contant (Csubf and Cmusl) of carcass;
Cut parameters (%): Rfat - Proximate fat content of cut; Rprot - Protein content of cut; Rmoist - Moisture content of cut; Tsubf - Subcutaneous fat of cut; Tmusl - Muscle content of cut; Tbone - Bone content of cut; Tmeat - Meat content (Tsubf and Tmusl) of cut; SEfat - Proximate fat in cooked muscle; *Transformations:* LN - Log X; SQ -$\sqrt{x}$; KW – X^2; TR – X^3

[2] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

TABLE 3
Forward Stepwise Regression Analysis For The Prediction Of Tenderness For The B Age Group Without Sensory Evaluation Scores

Muscle	Attribute[1]	R^2	p-Value	Regression Coefficient	Standard error of Obsrevation
LTP[2]	Constant			8,05	0,71
	Instron	55,1	0,001	-0,02	0,004
	KWTsubf	65,3	0,001	0,01	0,004
	Csubf	71,3	0,001	-0,17	0,08
LL	Constant			7,88	0,89
	Instron	43,5	0,001	-0,06	0,05
LTW	Constant			8,25	0,64
	Instron	65,7	0,001	-0,03	0,01
ST	Constant			8,87	0,71
	Instron	58,2	0,001	-0,04	0,007
GM	Constant			13,46	1,23
	Cbone	20,6	0,029	-0,27	0,05
	Instron	69,9	0,001	-0,04	0,01
SM	Constant			3,89	1,03
	Instron	42,3	0,002	-0,02	0,005
	Tbone	52,6	0,001	0,31	0,08
	Rfat	74,6	0,001	0,10	0,03
PM	Constant			7,71	0,59
	Instron	17,6	0,042	-0,02	0,007
GB	Constant			8,27	0,91
	Instron	45,0	0,001	-0,03	0,008
VL	Constant			7,43	0,55
	Instron	46,8	0,001	-0,20	0,05
SV	Constant			8,38	0,54
	Instron	72,6	0,001	-0,05	0,008
PP	Constant			7,23	1,11
	Instron	43,3	0,016	-0,66	0,22
BC	Constant			4,33	0,35
	TRRfat	47,1	0,012	0,00006	0,00002
TBCL	Constant			10,66	2,14
	Rprot	34,8	0,020	-0,29	0,11
OAE	Constant			7,83	0,91
	Instron	40,4	0,021	-0,03	0,009
ECR	Constant			6,36	0,61
	Instron	57,7	0,001	-0,05	0,01
FDM	Constant			4,34	0,59
	Instron			-0,03	0,01

[1] *Carcass parameters (%):* Cfatcr - Proximate fat content of carcass; Csubf - Subcutaneous fat of carcass; Cmusl - Muscle content of carcass; Cbone - Bone content of carcass; Cmeat - Meat contant (Csubf and Cmusl) of carcass;
Cut parameters (%): Rfat - Proximate fat content of cut; Rprot - Protein content of cut; Rmoist - Moisture content of cut; Tsubf - Subcutaneous fat of cut; Tmusl - Muscle content of cut; Tbone - Bone content of cut; Tmeat - Meat content (Tsubf and Tmusl) of cut; SEfat - Proximate fat in cooked muscle; *Transformations:* LN - Log X; SQ -$\sqrt{x}$; KW – X^2; TR – X^3

[2] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*

TABLE 4
Forward Stepwise Regression Analysis[1] For The Prediction Of Tenderness For The C Age Group Without Sensory Evaluation Scores

Muscle	Attribute[1]	R^2	p-Value	Regression Coefficient	Standard error of Obsrevation
LTP[2]	Constant			9,73	1,01
	Instron	65,3	0,001	-0,03	0,004
	Tbone	71,9	0,001	-0,11	0,05
LL	Constant			11,37	2,00
	Instron	39,0	0,001	-0,04	0,009
	Cbone	52,5		-0,29	0,12
LTW	Constant			7,67	0,46
	Instron	75,1	0,001	-0,03	0,004
ST	Constant			10,02	0,84
	Instron	68,4	0,001	-0,05	0,007
GM	Constant			11,48	1,60
	Cbone	33,9	0,003	-0,29	0,10
	Instron	50,2	0,001	-0,02	0,01
SM	Constant			6,27	0,56
	Instron	35,9	0,003	-0,01	0,004
PM	Constant			9,46	0,98
	Instron	35,6	0,001	-0,04	0,01
GB	Constant			6,85	1,15
	Instron	32,7	0,004	-0,02	0,004
	LNTsubf	42,3	0,003	0,82	0,27
	SQCfatcr	52,4	0,001	-0,61	0,28
VL	Constant			7,34	0,44
	Instron	66,3	0,001	-0,22	0,04
SV	Constant			-5,9	5,02
	Instron	53,6	0,001	-0,02	0,006
	Tmusl	65,5	0,001	0,14	0,06
PP	Constant			4,40	0,65
	Instron	23,5	0,039	-0,27	0,12
BC	Constant			10,69	3,21
	Rprot	20,9	0,057	-0,34	0,16
TBCL	Constant			6,16	0,94
	Instron	18,3	0,055	-0,02	0,009
OAE	Constant			6,74	0,92
	Instron	25,8	0,031	-0,02	0,008
ECR	Constant			4,49	0,33
	Instron	41,0	0,006	-0,02	0,004
FDM	Constant			6,34	0,70
	Instron			-0,02	0,003

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[1] *Carcass parameters (%):* Cfatcr - Proximate fat content of carcass; Csubf - Subcutaneous fat of carcass; Cmusl - Muscle content of carcass; Cbone - Bone content of carcass; Cmeat - Meat contant (Csubf and Cmusl) of carcass;
Cut parameters (%): Rfat - Proximate fat content of cut; Rprot - Protein content of cut; Rmoist - Moisture content of cut; Tsubf - Subcutaneous fat of cut; Tmusl - Muscle content of cut; Tbone - Bone content of cut; Tmeat - Meat content (Tsubf and Tmusl) of cut; SEfat - Proximate fat in cooked muscle; *Transformations:* LN - Log X; SQ -$\sqrt{x}$; KW – X^2; TR – X^3

[2] LTP - *M. longissimus thoracis*; LL - *M. longissimus lumborum*; LTW - *M. longissimus thoracis*; ST - *M. semitendinosus*; GM - *M. gluteus medius*; SM - *M. semimembranosus*; PM - *M. psoas major*; GB - *M. gluteobiceps*; VL - *M. vastus lateralis*; SV - *M. serratus ventralis*; PP - *M. pectoralis profundus*; BC - *M. biventer cervicis*; TBCL - *M. triceps brachii caput longum*; OAE - *M. obliquus abdominis externus*; ECR - *M. extensor carpi radialis* and FDM - *M. flexor digitorum medialis*