Chemical and essential amino acid composition of South African Mutton Merino lamb carcasses

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The essential amino acid composition of carcasses from South African Mutton Merino ram lambs fed a standard diet was investigated. Twenty lambs were randomly allocated to four pre-assigned average slaughter weights (30, 35, 40 and 45 kg live weight). The chemical composition (moisture, fat, protein and essential amino acids) of the carcass, three rib cut, *M. longissimus dorsi, M. infraspinatus flexor,* and *M. biceps femoris* was determined.The moisture and fat percentage of the three rib cut revealed the highest correlation when compared to that of the carcass. Non-significant correlations ($p > 0.05$) occurred between the carcass protein and the protein percentage of the three rib cut and each of the muscles. Low coefficients of determination (r^2) were obtained when prediction equations for individual essential amino acid concentration in the carcass from the three rib cut or muscles as well as the protein percentage of the carcass were formulated. The essential amino acid composition of the carcass, three rib cut and muscles remained similar regardless of slaughter weight. Isoleucine, lysine, methionine, phenylalanine and valine concentrations were significantly different ($p < 0.05$) either in the three rib cut or at least in one of the muscles when compared to the carcass. The carcass essential amino acid composition (g AA / 100 g protein) was as follows: 6.94 arginine; 2.61 histidine; 3.19 isoleucine; 7.19 leucine; 7.03 lysine; 2.08 methionine; 4.15 phenylalanine; 3.79 threonine and 4.28 valine. This composition can serve as an example of the ideal protein (amino acids) requirements for carcass growth of South Afiican Mutton Merino ram lambs.

'n Ondersoek is ingestel na die karkas essensiële aminosuursamestelling van Suid-Afrikaanse Vleismerino ramlammers, wat 'n standaarddieet ontvang het. Twintig lammers is ewekansig aan vier voorafbepaalde slagmassas (30, 35, 40 en 45 kg lewendegewig) toegewys. Die chemiese samestelling (vog, vet, proteïen en essensiële aminosure) van die karkas, drie-ribsnit, *M. longissimus dorsi, M. infraspinatus, flexor* en *M. biceps femoris* is bepaal. Die drie-ribsnit het die hoogste korrelasie met vog- en vetpersentasies in die karkas getoon. Die korrelasies tussen die drie-ribsnit of elk van die spiere en die proteïenpersentasies in die karkas was nie betekenisvol nie ($p > 0.05$). 'n Lae bepalingskoëffisient (r^2) het tydens die formulering van voorspellingsvergelykings vir individuele essensiële aminosuurkonsentrasies in die karkas vanaf die drie-ribsnit- of spierproteïeninhoud, asook die proteïeninhoud van die karkas voorgekom. Die essensiële aminosuursamestelling van die karkas, drie-ribsnit en spiere is nie deur slagmassa beïnvloed nie. Daar was betekenisvolle verskille ($p < 0.05$) in die konsentrasies van isoleusien, lisien, metionien, fenielalanien en valien van die drie-ribsnit of ten minste een van die onderskeie spiere in vergelyking met dié van die karkas. Die essensiële aminosuursamestelling van die karkas (g aminosuur/100 g proteïen) was soos volg: 6.94 arginien; 2.61 histidien; 3.19 isoleusien; 7.19 leusien; 7.03 lisien; 2.08 metionien; 4.15 fenielalanien; 3.79 treonien en 4.28 valien. Hierdie samestelling kan as voorbeeld van die ideale proteïenbehoeftes (aminosure) vir karkasgroei van Suid-Afrikaanse Vleismerinoramlammers dien.

Keywords: essential amino acids; carcass, sheep

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Introduction

Ruminants utilize protein for growth most efficiently when provided with a supply of amino acids that matches tissue requirements (Mantysaari *et al.*, 1989 and Hussein *et al.*, 1991). According to Williams *et al.* (1954), the chemical and amino acid composition of the carcass of animals (ideal protein) is a good predictor of their tissue requirements.Therefore, the total tissue amino acid composition is an essential ingredient in assesing dietary requirements, and information on the extent of this variation is therefore required (Williams, 1978). The amino acid requirements of the individual tissues may also vary at different physiological stages and since very little attention has been directed towards this statement (MacRae *et al.*, 1993), additional work should also focus on the amino acid composition of the carcass at progressive stages of growth to determine the amino acid requirements essential for carcass gain. Several studies regarding the use of carcass amino acid composition as a criterion to determine the amino acid requirements of cattle have been published (Williams *et. al.*, 1954, Griffiths, 1977 and Williams & Hewitt, 1979). The use of carcass amino acid composition to predict the requirements for growing lambs seems to be limited, and only confined to the work of Smith (1980), MacRae *et.al.* (1993) and Cole & Van Lunen (1994).

South African Mutton Merino lambs are predominantly used in South African feedlots and thus play a major role in the production of mutton. Since there is no information regarding the essential amino acid requirements of these animals, further research is required.

To determine the amino acid composition of the carcass, at least half the carcass has to be milled, thoroughly mixed and a representative sample taken for analysis (MacRae *et al.*, 1993). The high mutton prices and high cost to rear sheep, as well as the wastage of at least half a carcass to determine its amino acid composition, makes this method of estimating amino acid requirements at tissue level expensive and thus difficult to finance. Estimation of carcass composition without sacrificing the entire carcass is thus an important factor to be considered. Since the composition of the three rib cut (9-10-11 rib section) has been used widely to predict carcass chemical composition (Hankins & Howe, 1946; Kirton & Barton, 1962; Crouse & Dikeman, 1974; Nour *et al.*, 1981 and Nour & Thonney, 1994), certain carcass cuts or muscles may also be used with varying degrees of accuracy to obtain an estimate of the amino acid composition of the carcass.

Several authors (Smith, 1980; Lawrie, 1985; Gilka *et al.*, 1989 and Chen & Ørskov, 1994) have published measurements of the amino acid composition of meat and sheep carcasses. MacRae *et al.*, (1993) also made comparative slaughter measurements on the protein and amino acid percentage of lamb tissue, but no comparative studies of the amino acid composition of various cuts or muscles of the sheep carcass could be found in the available literature. It is thus important that the amino acid composition of various cuts and muscles be compared with that of the carcass to possibly specify a cut or muscle that is representative of the whole carcass.

The use of the *M. longissimus dorsi, M. infraspinatus, flexor* or *M. biceps femoris* to predict moisture, protein, fat or amino acid percentage of the carcass has not been found in the available literature. Therefore, this aspect was also investigated in the present study. The purpose of this study was:

(a) to determine the essential amino acid composition (requirements) of South African Mutton Merino lamb carcasses at different live weights and
(b) to compare the chemical composition (moisture, protein, fat and essential amino acids) of various cuts and muscles with that of the carcass.

Material and methods

Twenty closely shorn South African Mutton Merino ram lambs were used for the study. A standard growing diet (Table 1), fed *ad libitum*, was formulated to provide in the nutrient requirements of growing lambs (NRC, 1985). Five lambs, randomly selected, were used to determine the digestible energy content of the basal diet. The feeds used to formulate this diet were those that are reasonably available in South Africa.

Twenty lambs were randomly allocated to four groups of five each. Each group was in turn randomly allocated to a specific pre-assigned average slaughter weight (30, 35, 40 and 45 kg). Each animal was individually weighed and slaughtered when the average desired weight of a group was reached. This was done by using an abattoir pistol followed by exsanguination. The head and feet, skin, liver, lungs, heart, spleen, kidneys and gastrointestinal tract were removed from the carcass. From the right side (Kirton & Barton, 1962; Ainslie *et al.*, 1992) of the equally halved carcass, the following components, including the subcutaneous fat, were extracted: three rib cut (9-10-11 rib section), flexor, *M. longissimus dorsi, M. biceps femoris* and *M. infraspinatus*. The flexor was carefully removed in order to ensure that it consisted of the *M. flexor digit. profundus, M. flexor digit. superficialis, M. flexor carpi ulnaris* and *M. flexor carpi radialis*. The posterior portion (behind the three rib cut) of the *M. longissimus dorsi* was carefully removed from the vertebrae whereas the *M. biceps femoris* and *M. infraspinatus* were removed from the right hind leg and right shoulder, respectively. Each component, including the left side of the carcass, was accurately weighed and stored at −18°C prior to processing. The three rib cut was selected owing to its previous use in predicting carcass composition (Kirton & Barton, 1962; Crouse & Dikeman, 1974; Nour *et al.*, 1981 and Nour & Thonney, 1994) and the *M. longissimus dorsi*, because of its use in determining meat amino acid composition (Gilka *et al.*, 1989). The flexor, *M. infraspinatus* and *infraspinatus* and *M. biceps femoris* were selected owing to easy accessibility and minimal damage caused to the whole carcass when removed by dissection. These cuts and muscles were also representative of different parts of the carcass.

The left half of the carcass and right three rib cut were individually milled, mixed and milled again through a carcass mill while in the frozen state. The flexor, *M. longissimus dorsi, M. biceps femoris* and *M. infraspinatus* were also indi-

Table 1 Physical and chemical composition of the basal diet on an air dry basis

Item	Content
Physical composition	
Lucerne (%)	30.00
Wheat straw (%)	8.00
Maize meal (%)	56.25
Molasses meal (%)	3.50
Urea (%)	1.00
Salt (%)	0.50
Ammonium chloride (%)	0.75
Taurotec[1] (g/t)	290.00
Chemical composition	
Dry matter (%)	93.26
Crude protein (%)	14.72
Crude fibre (%)	13.96
Neutral detergent fibre (%)	33.37
Acid detergent fibre (%)	13.61
Ether extract (%)	4.99
Ash (%)	7.93
Calcium (%)	0.52
Phosphorus (%)	0.34
Metabolizable energy[2] (MJ/kg)	10.79

[1] A growth promotor grams per ton

[2] Metabolizable energy (ME) = Digestible energy (DE) × 0.82 (NRC, 1985)

vidually minced, mixed and minced again with a mincer. After thoroughly mixing each individual component again, a representative sample was freeze-dried. After freezing the freeze-dried sample at −18°C, it was mixed with dry-ice and milled through a l-mm screen, thoroughly mixed and stored at −18°C for later analysis. The dry-ice was used to prevent fat from smearing in the milling machine.

The diet, faeces, carcass and cuts were analysed for moisture, ash, crude protein, ether extract, calcium and phosphorus according to the methods of Harris (1970) and A.O.A.C. (1984). The acid detergent fibre and neutral detergent fibre were analysed using a Tecator Fibretec System (Van Soest, 1963 and Van Soest & Wine, 1967). Gross energy was determined using an adiabatic bomb calorimeter (DDS 400: Digital Data Systems). The amino acid composition of the representative samples was determined with a BECKMAN SYSTEM 7300 high performance analyser after 22 h of acid hydrolysis (6 N.HCl) at 110°C according to A.O.A.C. (1984).

Regression analysis, one-way ANOVA and multiple comparisons (using Tukey's test) were performed on the data using PC SAS 6.04 (Cary, NC: SAS Institute Inc.). Guidelines were followed from the SAS Procedures Guide (1988) and second edition of SAS System for Regression (1991). The correlation of mean values with a r^2-value larger than 0.19 was found to be significant ($p < 0.05$), whereas r^2-values larger than 0.31 were highly significant ($p < 0.01$).

Results and discussion

Moisture, protein and fat percentage

The moisture, protein and fat percentages of the carcass, three rib cut and muscles are presented in Table 2. The moisture percentages of the muscles were significantly higher ($p < 0.05$) than that of the three rib cut and carcass. The lower moisture percentage is most likely the result of the high percentage of bone and fat in the carcass and three rib cut. The latter is indirectly supported by Kirton & Barton (1962), Farid (1991), Nour & Thonney (1994) and Kock *et al.* (1995), who observed high negative correlations between fat and moisture percentages of the carcass.

From Table 3 it is evident that the percentages of moisture in all four muscles, as well as the three rib cut, were significantly correlated ($p < 0.05$) when compared to that of the carcass. The highest correlation ($p < 0.01$) with an r^2-value of 0.87 occurred between the three rib cut and carcass moisture. Ainslie *et al.* (1993) also observed a high correlation (r^2 = 0.70) between carcass water and three rib cut water. With the exception of the flexor, the fat percentages of the three rib cut and remaining muscles were also significantly correlated ($p < 0.05$) with that of the carcass (Table 3). Similar to moisture percentage, the highest correlation for fat was found between the three rib cut and carcass. The correlations between carcass protein and protein percentage of the three rib cut and muscles were surprisingly lower than the correlation for moisture and fat. In fact, no significant correlations ($p > 0.05$) occurred between carcass protein percentage and protein percentage of the three rib cut or each of the muscles.

The above-mentioned finding was supported by Ainslie *et al.* (1993) who also observed a protein prediction equation with low correlation ($r^2 = 0.02$) between carcass and three rib cut protein. Kirton & Barton (1962) could not give a satisfactory explanation for the lower correlation between carcass protein per cent and protein per cent of each of the three parts (leg, half loin, rib cut and fore) used during their study. Ainslie *et al.* (1993) was of the opinion that the non-significant correlation was due to small variation ($CV = 2.5\%$) in carcass and three rib cut protein. In contrast to the above findings, several authors (Crouse & Dikeman, 1974; Nour *et al.*, 1981 and Nour & Thonney, 1994) have considered the three rib cut to be a useful predictor of the entire carcass chemical composition of animals. Conflicting results have thus occurred in the available literature with regard to the prediction of carcass protein from the three rib cut.

Table 2 Mean moisture, fat and protein composition (± *SD*) of the carcass, three rib cut and muscles (%)

	Carcass	Three rib cut	*M. longissimus dorsi*	*M. infraspinatus*	Flexor	*M. biceps femoris*
Moisture	54.01^c	52.25^d	72.22^b	73.69^a	73.13^{ab}	73.40^{ab}
SD	±2.33	±1.89	±1.17	±0.87	±1.13	±0.86
Protein	18.53^a	18.74^a	20.70^a	19.63^a	21.23^a	20.72^a
SD	±0.62	±0.61	±0.86	±0.71	±1.11	±0.68
Fat	23.10^b	25.23^a	6.06^c	5.32^{cd}	3.90^d	6.06^c
SD	±2.86	±2.71	±0.77	±0.46	±0.22	0.53

^{a,b,c,d} Values in rows bearing different superscript letters are significantly different ($p < 0.05$)

Table 3 Regression equations for predicting moisture, protein and fat (%) of lamb carcasses and the coefficients of determination (r^2) between the dependent and independent variates

Independent variate (X)	Dependent variate (Y)	r^2	Regression equation $Y = b_0 + b_1X$	Std. Err of Y-estimate
Moisture content				
Three rib cut	Carcass	0.87**	$Y = -6.04 + 1.15(X)$	0.87
M. longissimus dorsi	Carcass	0.67**	$Y = -63.15 + 1.62(X)$	1.37
M. infraspinatus	Carcass	0.44**	$Y = -77.14 + 1.78(X)$	1.79
Flexor	Carcass	0.66**	$Y = -68.76 + 1.68(X)$	1.39
M. biceps femoris	Carcass	0.73**	$Y = -16.68 + 2.33(X)$	1.24
Protein content				
Three rib cut	Carcass	0.06	$Y = 13.82 + 0.25(X)$	0.62
M. longissimus dorsi	Carcass	0.003	$Y = 19.30 + 0.04(X)$	0.64
M. infraspinatus	Carcass	0.02	$Y = 21.16 - 0.13(X)$	0.63
Flexor	Carcass	0.002	$Y = 17.93 + 0.03(X)$	0.64
M. biceps femoris	Carcass	0.06	$Y = 13.78 + 0.23(X)$	0.62
Fat content				
Three rib cut	Carcass	0.80**	$Y = 0.71 + 0.94(X)$	1.31
M. longissimus dorsi	Carcass	0.47**	$Y = 7.63 + 2.55(X)$	2.15
M. infraspinatus	Carcass	0.53**	$Y = 0.89 + 4.51(X)$	2.02
Flexor	Carcass	0.03	$Y = 31.74 - 2.22(X)$	2.89
M. biceps femoris	Carcass	0.53**	$Y = -0.47 + 3.88(X)$	2.00

* $p < 0.05$; ** $p < 0.01$

Essential amino acid composition

No significant correlations ($p > 0.05$) occurred between empty body weight measured at slaughter and the essential amino acid percentage of the carcass, three rib cut and muscles (*M. longissimus dorsi, M. infraspinatus*, flexor and *M. biceps femoris*). The essential amino acid composition (g AA / 100 g protein) remained similar regardless of slaughter weight and data were therefore pooled. MacRae *et al.* (1993) experienced similar results during their comparative slaughter study with growing lambs.

Relatively few publications (Seifter & Gallop, 1966; quoted by Williams, 1978 and Smith, 1980) are concerned with possible changes in the amino acid composition of carcass or muscle tissue during the growth of animals. This results from the knowledge that the composition of muscle protein is genetically determined and, therefore, is not expected to change even if the conditions during growth (e.g., the quality and quantity of the diet or the health status) were different (Gilka *et al.*, 1989). On the other hand, one cannot ignore the fact that the proportion of muscle and tissue (especially connective tissue) may vary with increasing age (Smith, 1980). This factor, however, seems to have no influence on the essential amino acid percentage of the lamb carcass at the weight range implemented in the present study. The reason might be due to the relatively short duration of the experiment (73 days) and thus insignificant ageing of the lambs.

Table 4 lists the mean essential amino acid composition of the carcass as compared to that obtained from the three rib cut and muscles. The average arginine, histidine and threonine percentages of the three rib cut and muscles did not differ significantly ($p > 0.05$) from the carcass. In contrast, the isoleucine, leucine, lysine, methionine, phenylalanine and valine concentrations showed significant differences ($p < 0.05$) either in the three rib cut or at least in one of the muscles when compared to that of the carcass.

With the exception of arginine and threonine, the carcass and three rib cut contained, in general, a lower concentration of most essential amino acids, particularly leucine and lysine, when compared to that of muscles. These findings are in agreement with the work of Ainslie *et al.* (1993), who accordingly reported that the amino acid values were higher when determined on selected muscle tissue rather than on the whole carcass. Collagen, the main protein component of muscle connective tissue, tendons and skin, is poor in all the essential amino acids except arginine (Seifter & Gallop, 1966; quoted by Williams, 1978). This probably contributed to the generally lower essential amino acid percentage (except arginine) in the carcass and three rib cut. In addition, the major protein constituents of muscle are myosin and actin, which have a high, well-balanced essential amino acid contents (Williams, 1978). This may also contribute to the explanation of a higher essential amino acid content observed in the muscle in comparison to the carcass and three rib cut.

Significant correlations ($p < 0.05$) occurred when the isoleucine and phenylalanine percentages of the *M. longissimus dorsi* or *M. infraspinatus* were compared to those of the carcass. These correlations, however, exhibited r^2-values that varied between 0.20 and 0.27. Therefore, only 20 to 27% of the variation in carcass isoleucine or phenylalanine percentage can be accounted for by that of the *M. longissimus dorsi* or *M. infraspinatus*. In contrast, no significant correlations ($p > 0.05$) occurred for the remaining essential amino acids in any particular cut or muscle when compared to that of the carcass. Since protein, and therefore amino acids, does not vary

Table 4 Mean essential amino acid composition (±*SD*) of carcass, three rib cut and muscles (g AA/100 g protein)

	Carcass	Three rib cut	*M. longissimus dorsi*	*M. infraspinatus*	Flexor	*M. biceps femoris*
Arginine	6.94^{ab}	7.57^{a}	6.88^{ab}	6.67^{b}	6.77^{ab}	6.99^{ab}
SD	±0.49	±0.65	±0.86	±0.99	±0.74	±1.02
Histidine	2.61^{abc}	2.52^{bc}	2.89^{a}	2.37^{cd}	2.48^{bc}	2.70^{ab}
SD	0.58	±0.16	±0.27	±0.13	±0.25	±0.24
Isoleucine	3.19^{c}	3.98^{ab}	4.21^{a}	3.55^{bc}	3.56^{bc}	4.21^{a}
SD	±0.23	±0.79	±0.48	±0.72	±0.41	±0.42
Leucine	7.19^{d}	7.72^{c}	8.32^{ab}	8.07^{bc}	8.60^{a}	8.71^{a}
SD	±0.40	±0.47	±0.55	±0.56	±0.35	±0.42
Lysine	7.03^{d}	7.06^{d}	8.56^{a}	7.89^{bc}	7.84^{c}	8.52^{ab}
SD	±0.46	±0.86	±0.52	±0.75	±0.48	±0.49
Methionine	2.08^{cde}	2.07^{de}	2.41^{ab}	2.27^{bcd}	2.29^{bc}	2.57^{a}
SD	±0.23	±0.25	±0.16	±0.26	±0.20	±0.17
Phenylalanine	4.15^{d}	4.82^{abc}	4.37^{cd}	4.53^{bcd}	4.24^{d}	5.09^{a}
SD	±0.37	±0.44	±0.37	±0.52	±0.79	±0.56
Threonine	3.79a	3.82a	3.74a	3.66a	3.65a	3.82a
SD	±0.26	±0.76	±0.31	±0.45	±0.23	±0.28
Valine	4.28^{bc}	4.60^{ab}	4.81^{a}	3.96^{cd}	3.60^{d}	4.76^{a}
SD	±0.40	±0.53	±0.41	±0.60	±0.28	±0.39

^{a,b,c,d,e} Values in rows bearing different superscript letters are significantly different ($p < 0.05$).

Table 5 Essential amino acid composition of muscle and carcass of lamb (g AA/100 g protein)

Literature	Arg	His	Ile	Leu	Lys	Met	Phe	Thr	Val
Smith (1980)[1]	–	2.8	5.1	7.8	8.3	2.3	4.1	4.6	5.1
Lawrie (1985)[2]	6.9	2.7	4.8	7.4	7.6	2.3	3.9	4.9	5.0
Gilka *et al.*, (1989)[3]	5.1	4.1	4.0	5.4	8.7	1.9	2.9	3.9	4.1
MacRae *et al.*, (1993)[4]	7.3	2.6	3.8	7.5	7.0	1.8	3.9	5.0	4.9
Chen & Ørskov (1994)[5]	6.1	3.2	4.6	7.2	9.8	2.6	3.8	4.6	4.8
Present study (1995)	6.9	2.6	3.2	7.2	7.0	2.1	4.2	3.8	4.3
Average[6]	7.1	2.6	3.5	7.4	7.0	2.0	4.1	4.4	4.6
Beef carcass[7]	6.9	2.6	3.1	6.9	6.7	2.0	3.5	4.0	4.0

[1] Represents values reported by FAO (1970)

[2] Values described as the amino acid composition of fresh meat

[3] Values determined from *M. longissimus dorsi* of lamb

[4] Values determined from Suffolk × Finn Dorset carcasses

[5] Values described as 'Lean of lamb'

[6] Average of the carcass values (MacRae *et al.*, 1993 and present study, 1995)

[7] Average amino acid composition of beef carcasses determined from the results of William (1978) and Ainslie *et al.*, (1993)

much over this range, a significant regression is highly unlikely.

Table 5 compares the essential amino acid composition of lamb carcasses determined in the present study with others reported in the literature. When threonine was disregarded, the essential amino acid profile of the present study compared favourably with that of MacRae *et al.* (1993). The difference in threonine concentration is difficult to explain. With the exception of Gilka *et al.* (1989), the remaining studies in Table 5 reported higher values for most essential amino acids, apparently because they were determined on selected muscle tissue rather than on the whole carcass (Williams, 1978 and Ainslie *et al.* 1993).

From Table 5 it is clear that the average essential amino acid composition of the lamb carcasses in the present study corresponds with that of beef carcasses. This finding supports the view of Smith (1980) who mentioned that the amino acid composition of the body of animal species is remarkably similar. However, Smith (1980) added that variations do occur. For an accurate estimation, it appears to be necessary to establish the amino acid composition for specific species.

As the methods to analyse individual amino acids in animal carcasses are costly, an alternative could be preferable to predict the amino acid concentration from the protein concentration of the carcass. The prediction equations formulated from the data of the present study have no high coefficients of determination (r^2). The use of this method to predict the essential amino acid concentration of the carcasses is thus debatable. Before these regression equations can be applied, further research is needed to validate this alternative method of predicting the essential amino acid concentrations in the carcass.

Conclusions

From the results of the present study, it can be concluded that the moisture and fat percentage of the three rib cut was most closely related to that of the carcass. However the three rib cut, *M. longissimus dorsi, M. infraspinatus,* flexor and *M. biceps femoris* were not suitable to predict the essential amino acid composition of South African Mutton Merino lamb carcasses. The prediction of the essential amino acid concentration from the protein percentage of the carcass also appears to be an unreliable method. The essential amino acid composition of the carcass, three rib cut and muscles remained similar regardless of slaughter weight. With the exception of arginine, histidine and threonine, the concentration of the remaining essential amino acids studied showed significant differences ($p < 0.05$) either in the three rib cut or at least in one of the muscles when compared to the carcass. The average essential amino acid composition of the carcasses determined in the present study could serve as an ideal example of the essential amino acid requirements of South African Mutton Merino ram lambs for carcass growth at tissue level.

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