The effect of slaughter age on the lamb characteristics of Merino, South African Mutton Merino and Dorper lambs

by

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DECLARATION

By submitting this thesis electronically, I declare that entirety of the work contained therein is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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SUMMARY

The aim of this study was to investigate the effect of feedlot production on the growth and carcass characteristics, as well as the distribution of the main tissues (muscle, fat and bone) and meat quality of Merino, South African Mutton Merino (SAMM) and Dorper lambs.

The Merino and SAMM 2008 outperformed (P<0.05) the 2007 SAMM and both Dorper production groups in terms of average daily gain, while the Merino and both SAMM production groups achieved the best feed conversion ratio (P<0.05). The highest percentage A2 graded carcasses was achieved after 42 days under feedlot conditions by the Merino and both Dorper production groups, but it took only 21 days in the feedlot for the SAMM lambs to achieve the same result.

Slaughter weight, carcass weight and dressing percentage all increased significantly with an increase in the number of days under feedlot conditions for all three breeds, while a decrease in the percentage head, trotters and red offal was also documented. The fatter retail cuts (thick rib, flank, prime rib and loin) increased (P<0.05) in percentage with an increase in the number of days under feedlot conditions. A significant decrease in the percentage leaner retail cuts (raised shoulder and hind-quarters) was found when the amount of days under feedlot conditions increased. The highest profit is obtained by the prime rib, loin and hind-quarters in a lamb carcass. For the Merino and Dorper lambs these three cuts, or a combination of the three showed the highest combined percentages after 42 and 63 days under feedlot conditions, respectively. The late maturing SAMM lambs achieved the highest percentages for these three cuts after 63 and 84 days under feedlot conditions in 2007 and 2008 respectively.

Visceral and renal fat deposition increased throughout the production period for all breeds. The Dorper lambs attained the highest subcutaneous fat depth, and also produced the heaviest, but fattest carcasses. For A2-graded carcasses, Dorper lambs had the highest dressing percentage and lowest subcutaneous fat depth, followed by the SAMM and then Merino breed. A decrease in the percentage muscle and bone was found with an increase in the number of days under feedlot conditions, whilst an increase in the percentage fat was found under the same conditions.

Meat quality was mostly affected by the 48h *post mortem* pH. This pH value is affected by the cooling rate of the carcasses, which in turn is affected by the level of carcass fatness. Carcass fatness increased with an increase in the number of days under feedlot conditions, resulting in a low 48h *post mortem* pH. A low 48h *post mortem* pH is accompanied by higher percentages of cooking and drip loss, as well as a high a*-colour reading for all three breeds.

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OPSOMMING

Die doel van hierdie studie was om die effek van voerkraalproduksie op die groeivermoë, karkas-eienskappe, verspreiding van spier, been en vet, en vleiskwaliteit van Merino, Suid-Afrikaanse Vleismerino (SAVM) en Dorperlammers te bepaal.

Die Merino en SAVM 2008 produksiegroepe het hoër ($P<0.05$) gemiddelde daaglikse toenames getoon as die SAVM 2007 en beide Dorper groepe, terwyl die Merino en beide SAVM produksiegroepe die beste voeromset verhoudings bereik het ($P<0.05$). Die hoogste persentasie A2 gegradeerde karkasse is na 42 dae in die voerkraal deur die Merino en beide Dorper produksiegroepe geproduseer, terwyl dit slegs 21 dae onder dieselfde toestande vir die SAVM groepe geneem het om dieselfde resultaat te lewer.

Daar is ‘n betekenisvolle verhoging in slagmassa, karkasmassa en uitslagpersentasie vir al drie die rasse gevind met ‘n toename in die aantal dae in die voerkraal, terwyl ‘n afname in die persentasie kop, pote en haarslag gevind was. Die persentasie vetter groothandelsnitte (dikrib, dunrib, ribtjop en lendesnit) het toegeneem ($P<0.05$) met ‘n toename in die aantal dae in die voerkraal. ‘n Betekenisvolle afname in die persentasie van die maerder groothandelsnitte (blad en boude) is gevind met ‘n toename in die aantal produksie dae in die voerkraal. Die hoogste inkomste van ‘n lamkarkas is afkomstige van die ribtjop, lende snit en boude. ‘n Kombinasie van hierdie drie snitte was die hoogste vir die lammers van die Merino en beide Dorper groepe na 42 en 63 dae in die voerkraal onderskeidelik. Die laat volwasse SAVM lammers het die hoogste persentasie van hierdie drie snitte bereik na 63 en 84 dae in die voerkraal vir die SAVM 2007 en SAVM 2008 onderskeidelik.

Die neerlegging van pensvet en niervet het voortdurend toegeneem deur die produksieperiode vir al drie rasse. Die Dorperlammers het die hoogste onderhuidse vetneerlegging getoon, maar het ook die swaarste en vetste karkasse geproduseer. Dorperlammers het die hoogste uitslagpersentasie en laagste onderhuidse vetneerlegging vir A2 gegradeerde karkasse gehad, gevolg deur die SAVM en Merino. ‘n Afname in die persentasie spier en been in karkasse is waargeneem namate die lammers langer in die voerkraal was, terwyl ‘n toename in die persentasie vet onder dieselfde omstandighede waargeneem is.

Die 48h *post mortem* karkas pH affekteer die meeste vleiskwaliteit eienskappe. Hierdie pH waarde word weer deur die tempo van karkasafkoeling beïnvloed, wat op sy beurt deur die vetheidsgraad van die karkas bepaal word. Die vetheid van karkasse het toegeneem met ‘n toename in die aantal dae in die voerkraal, wat ‘n lae pH waarde 48h *post mortem* tot gevolg gehad het. ‘n Lae 48h *post mortem* pH waarde het gelei tot hoër persentasies kook- en dripverliese en hoë a* kleurlesings vir al drie rasse.

Parts of this thesis have been presented at:

1. 54th International Congress of Meat Science and Technology, Cape Town, August 2008, in the form of a presentation and a poster.

Presentation

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Poster

Van der Westhuizen, E.J., Brand, T.S., Hoffman, L.C., Aucamp, B.B., 2008. The effect of gender on the fat distribution in Merino lambs.

2. 43rd SASAS Congress, Alpine Heath, July 2009, in the form of a poster

Poster

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LIST OF ABBREVIATIONS

ADG	Average daily gain
cm	Centimetre
DFD	Dark, firm and dry meat
FCR	Feed conversion ratio
LD	*Longissimus dorsi*
min	Minute
mm	Millimetre
N	Newton
NIRS	Near Infrared Reflectance Spectroscopy
PSE	Pale, soft and exudative meat
pHu	Ultimate pH
pH45	pH forty five minutes after the animal is bled
pH48	pH forty eight hours after the animal is bled
R^2	Coefficient of determination
r	Coefficient of variation
SAMM	South African Mutton Merino
s.e.	Standard error
WHC	Water holding capacity

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Language and style in this thesis are in accordance with requirements of the Postgraduate student manual of the Department of Animal Sciences of Stellenbosch University. This thesis represents a compilation of manuscripts; each chapter is an individual entity and some repetition between chapters is therefore unavoidable.

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Chapter 1

Literature review

1.1. General introduction

The small stock industry has demonstrated itself to be very versatile and adaptable over the past decades. Environments of practice range from arid, low productivity regions to fairly intensive enterprises in the pasture-cropping regions and intensive horticulture areas. The Western Cape contributes approximately 15% of small stock production to the national industries. Small stock farming is well adapted to complement the cropping, horticulture and viticulture that are typical to the region. Scarcity in both lamb and mutton will lead to an increase in meat prices. When this happens it becomes more profitable for farmers to finish off their lambs in feedlots, unless the feed prices are too high. Feedlot conditions will also be beneficial in conditions where lambs are unable to reach their desired slaughter mass on pasture and also in times of pasture scarcity. Feedlot rations are designed to maximize growth rate and minimize the number of days on feed (Notter *et al*., 1991).

The value of sheep carcasses depends on several factors, namely weight, body conformation, proportion of the main tissues (muscle, fat and bone), distribution of these tissues through the carcass, muscle thickness, pre-slaughter stress, carcass cooling, ageing regime and meat quality. According to Wood *et al*. (2007), meat flavour, tenderness and nutrition value (the most important quality attributes of meat to the modern consumer) are influenced by the amount and type of fat in the meat. However, many consumers also believe that excess fat consumption will increase their risk of cardiovascular diseases and increase their risk of colorectal cancer. Grunert (2006), stated that meat plays an essential role in nutrition for the modern consumer, as it provides protein, some vitamins and various minerals to consumers. Consumer demand for leaner meat is continuously changing. Naudé (1994) found a decrease from 32% in 1949 to 18% in 1981 and 13% in 1991 for the average fat content of target grade beef in South Africa. Recently, South African lamb with a fatness level of 2, which is the most frequently consumed in South Africa, was analyzed. Results showed that South African lamb contains, on average, only 9.01% fat (Schönfeldt & Gibson, 2008). The consumer demand for leaner meat puts a lot of pressure on farmers to supply carcasses that are acceptable to consumers.

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1.2. History of the different sheep breeds

1.2.1. Merino

The first Merino type sheep in South Africa was two Spanish Merino rams and four Spanish Merino ewes given to Colonel Jacob Gordon as a gift from the King of Spain (Merino Breeders Society, 2009). Cross breeding with other Merino type sheep (the American Vermont-, Australian-, Wanganella- and the Peppin type) resulted in the Merino breed known to us today (Merino Breeders Society, 2009).

The Merino is one of the most popular sheep breeds in South Africa, composing almost half of all sheep in South Africa (Campher *et al*., 1998). This breed can be found throughout South Africa, with areas ranging from the dry Northern Cape, to semi arid Karoo, the wet Western Cape, Natal and even the Eastern Cape. The Merino is a late maturing wool-type sheep and according to the Merino Breeders Society (2009), it is the only sheep in the world that’s able to produce 10-15% of its own live weight as wool. Fluctuations in the wool prices over the past decade has resulted in distinct changes in the South African Merino industry, involving the adaptation of the breeding strategy for Merino sheep to enable an improved meat production capability (Olivier, 1999). Until recent years lamb (meat) production has been a by-product of the wool industry but at present 65-88% of the total South African income from woolen sheep is derived from meat, with contributions being even higher in the case of mutton and dual-purpose sheep (Hoon *et al*., 2000).

The Australian Merino is known for its high incidence of dark, firm and dry (DFD) meat, resulting in the discarding of the carcass (Gardener *et al*., 1999), whilst in South Africa the Merino sheep produce carcasses of the highest quality (Cloete, 2007).

1.2.2. South African Mutton Merino

In 1932, the Department of Agriculture of South Africa imported 10 German Mutton Merino ewes. However, the breed underwent selection for both better wool quality and body conformation, and only in 1971 was its name changed to the South African Mutton Merino (SAMM) (Neser *et al*., 2000). The main selection criterion for the SAMM is meat production, and because the SAMM is a dual-purpose mutton-wool sheep (80 mutton: 20 wool), wool production plays a secondary role (South African Mutton Merino Breeders' Society, 2009).

The SAMM is a breed with excellent body conformation and balance. It is a strong, large frame breed (South African Mutton Merino Breeders' Society, 2009) known for its ability to produce slaughter lambs with a high growth rate at an early age, with good meat quality attributes (Cloete *et al*., 2004). With a feed conversion efficiency (FCE) of 3.91 in finishing lambs (between 25 kg and 42 kg live mass), the SAMM is rated the most successful mutton breed in South Africa in terms of growth rate (South African Mutton Merino Breeders' Society, 2009). The SAMM is a late maturing breed and therefore tend to put on fat at a later age than Dorper lambs. This characteristic enables it to produce carcasses of up to 28 kg and still obtain the best grading possible (South African Mutton Merino Breeders' Society, 2009).

The SAMM will adapt easily to a wide variety of environmental conditions, and its ability to efficiently convert feed into lean tissue, make it a popular breed for intensive production systems (Neser *et al*., 2000). This breed will obtain an average live weight of 35 kg in 100 days under extensive conditions, but will reach an average live weight of 56 kg in the same time period under intensive conditions (South African Mutton Merino Breeders' Society, 2009).

SAMM ewes can produce up to 4.8 litres of milk per day. When this milk production is compared to that of the Merino at 17 days *post partum*, the SAMM will have an approximate 30% higher milk yield. The birth mass of SAMM lambs are lower than Merino lambs, but this is a result of the breeds high fertility and fecundity (multiple births) (South African Mutton Merino Breeders' Society, 2009).

1.2.3. Dorper

The depression years that followed after the First World War caused a surplus in mutton and a slump in wool prices. This resulted in the attention shifting to the export of mutton and lamb (www.dorpersa.co.za, 2009). The Southern Africa fat-tail type sheep were both new and undesirable to the English grading system (Milne, 2000) and could not compete with the high quality mutton produced by New Zealand, Australia and Argentina. The need for a mutton sheep that can produce fast growing lambs with a good quality carcass was realized (www.dorpersa.co.za, 2009).

During the 1930's the Department of Agriculture of South Africa developed the Dorper sheep breed by crossing a Dorset Horn ram with a Blackhead Persian ewe (Milne, 2000). The Dorper is well recognized throughout Africa, Australia, the Middle East and North America for its meat and carcass characteristics, mothering ability and excellent growth potential (Schoeman, 2000). The breed has grown to be the second largest sheep breed in South Africa, and it accounts for the vast majority of meat producing sheep (Cloete *et al*., 2007).

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The Dorper sheep is regarded as an early maturing breed and will put on more localized fat at an earlier age (lower live weight) than later maturing breeds. This phenomenon is seen as a disadvantage that is amplified by favourable environmental conditions and intensive feeding regimes (Claasen, 2008).

1.3. The effect of production system on production, growth and carcass characteristics

1.3.1. Growth

Animal growth can be defined as an increase in body weight that is achieved by both hypertrophy and hyperplasia until a mature size is reached. The development of an animal can be defined as changes in body conformation and form until maturity is reached (Lawrie, 1998). The sigmodiale growth curve (S-shape curve), relating live weight to age is recognized by three distinct phases, starting with a slow growth phase, where an increase in age is accompanied by a small increase in live weight, followed by a rapid growth phase, and ending with a plateau phase where the growth of muscles, bones and vital organs has slowed down and fattening accelerates (Lawrie, 1998). Results from a study done by Rouse *et al*. (1970), indicate that the percentage of fat deposition was higher in the fore saddle than the hind saddle during the latter stages of development, which signifies the general concept that at heavier weights, lambs fatten in an anterior to posterior sequence. The order of tissue maturation is bone, followed by muscle and then fat (Rouse *et al*., 1970).

When dietary energy has been used for maximal bone and lean growth, the excess energy is used for fat accretion (Murphy *et al*., 1994). Negussie *et al*. (2003), showed that there is a significant difference in the proportion of fat deposition at the different stages of growth. An increase in the proportion of concentrate in the diet results in an increase in lamb growth rate (Santos-Silva *et al*., 2002). Genotype is the main dictator in maximum growth potential and development. However, environmental and nutritional factors can manipulate the actual growth rate and development obtained (Aberle *et al*., 2001).

1.3.2. Production system

Sheep raised for meat production form a significant part of the economy of many countries in the world. There is a large variation between these countries in climatic conditions, management procedures and in genotypes available. Some animals are grazed continuously outdoors with only limited supplementation of available pastures whereas others are housed from birth and fed scientifically formulated diets. Producing lambs in a feedlot is a major economical decision; as lambs produced in a feedlot reach their slaughter weights at a younger age than lambs grazing pasture (Notter *et al*., 1991). However, to achieve this an enhanced average daily gain (ADG) is required, resulting in the need for a more expensive feed, leading to a higher total production cost. Extensive production systems are associated with a lower production cost, but a lower ADG results in lambs, reaching their slaughter weight at a later stage (Notter *et al*., 1991).

Sheep production is set apart from any other livestock production in the world because each country or region has its own preferences in terms of the type of carcass and the specific weight of carcass produced (San˜ udo *et al*., 1998). The average sheep carcass weight produced throughout the world is 15 kg, a carcass weight of between 6 and 9 kg is required in countries such as Italy, Bangladesh and Peru, whereas the United States, Japan and Egypt produce carcasses between 27 and 30 kg to meet their consumer preferences (San˜ udo *et al*., 1998).

Research indicate that the modern day consumer prefers free-range produced products because it is perceived to be healthier and of higher quality (Davies *et al*., 1995; Harper & Makatouni, 2002; McEachern & Willock, 2004).

1.3.3. Diet

The average daily gain (ADG) for lambs produced on concentrate diets (238 g/day) is higher when compared to lambs grazing pasture (185 g/day) (Priolo *et al*., 2002) this effect is caused by the higher energy content in the concentrate ration (San˜ udo *et al*., 1998). By comparing low, medium and high energy diets given to lambs in a feedlot with similar ADG, the lambs receiving the high energy diet will attain a feed conversion efficiency that is superior to those receiving the low or medium energy level diet (Malik *et al*., 1996). An animals' voluntary feed intake is limited by metabolic factors and energy intake capacity, therefore, a lamb receiving a low energy diet need to eat more than a lamb receiving a high energy diet to obtain the same growth rate (Guertin *et al*., 1995).

Enhanced growth efficiency and improved growth rates have been documented in various sheep breeds receiving a high-energy diet (Haddad & Husein, 2004). A common practice to increase the energy level of a concentrate diet is to supplement it with dietary fat or oil. However, dietary fats, if not protected against ruminal digestion, should not exceed 5% in ruminant diets because of negative effects (Brand *et al*., 2001). These effects include a decrease in the protozoa population, which contributes to celluloses; a decrease in fibre digestibility, resulting in an adverse effect in production efficiency; and palatability problems with the diet is frequent (Johnson & McClure, 1973). These effects are less pronounced with saturated fatty acid supplementation than with polyunsaturated fatty acids (Doreau & Chilliard, 2007). When a fat level of more than 5% is needed in the diet, these fats should be rumen protected fats. When lipid inclusion level exceeds 10%, the action of the rumen microbes are affected negatively (McDonald *et al*., 2002).

In a study done by Priolo *et al*. (2002), lambs were raised in an intensive and extensive production system but slaughtered at the same live weight. Their results showed that the digestive tract of the lambs raised on pasture was more developed than those fed a concentrate diet, which is caused by a higher level of dry matter intake by the pasture-raised lambs. A more developed digestive tract and accompanying smaller fat covering found in pasture raised lambs will result in a lower dressing percentage (Borton *et al*., 2005).

1.3.4. Carcass

Summers *et al*. (1978), reported that as carcass fatness increased, the percentage of flank, breast and loin (fatter cuts) increased, but the percentage leg (the largest and leanest cut) decreased. These results are supported by the findings of Lambuth *et al*. (1970), who concluded that an increase in the amount of fat and bone in the carcass resulted in a decrease in the edible portion of the carcass, however, when carcass weight increased, the percentage bone decreased and the percentage fat increased. There exists a significant correlation, both positive and negative, between the percentage major wholesale cuts and carcass ether extract (Summers *et al*., 1978).

Lawrie (1998), stated almost no difference between sheep breeds in their ability to distribute muscles. Table 1, adapted from Casey (1982), shows results for two South African sheep breeds that support the statement of Lawrie (1998).

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Table 1 Comparison of carcass mass distribution between Merino and SAMM (adapted from Casey, 1982).

Breed	Slaughter mass (kg)	Fore limb (%)	Neck (%)	Ventral trunk (%)	Dorsal trunk (%)	Hind limb (%)
Merino	10	18.05	9.86	18.09	20.28	33.72
	23	16.03	8.93	23.10	20.76	31.20
	32	15.02	7.99	24.32	21.27	31.14
	41	14.95	8.32	25.96	20.85	29.92
	Average	16.01	8.78	22.87	20.73	21.56
SAMM	10	18.11	9.87	15.10	19.70	37.22
	23	16.28	7.85	20.84	20.31	34.72
	32	15.12	7.78	23.21	20.85	33.04
	41	14.82	7.84	24.37	21.53	31.44
	Average	16.08	8.33	20.88	20.60	34.11

1.4. Physical characteristics of sheep meat

1.4.1. Colour

When consumers purchase meat, the colour of the meat is the most important attribute associated with freshness of red meat (Kerry *et al*., 2000). This, however; is only true when meat odour is not detected first. The oxygenation of myoglobin, when meat is exposed to air, is responsible for the bright red colour of lamb meat. The concentration of haeme proteins such as haemoglobin, myoglobin and cytochrome C, their chemical states, the type of myoglobin present and the light scattering properties of meat are all factors influencing meat colour (Lawrie, 1998).

There are many options available for instrumental colour analysis, however; according to Stevenson *et al*., (1989), the CIELab colour space (Commission Internationale de l'Eclairage, 1976), expressing colour by the coordinates L*, a* and b*, are appropriate colour measures. Lightness in meat colour is represented by L* on a scale from 0 to 100, where 100 corresponds to pure white and 0 corresponds to pure black. A negative a* value indicates greenness and a positive a* value represents redness. A positive b* value indicates yellowness, while a negative b* value corresponds with blueness. Both a* and b* values are used to calculate the chroma value (C*) and hue angle (h_{ab}) by using the following equations: chroma value (C*) = $[(a^*)^2 + (b^*)^2]^{½}$, and the hue angle (º) = $\tan^{-1}$ (b*/a*) (Commission Internationale de l'Eclairage, 1976). The hue angle is expressed in degrees and defined as starting at the positive a* axis, the closer this angle gets to 270º, 180º and 90º the more the colour corresponds to blue, green and yellow, respectively. The chroma value is zero at the centre of the chromaticity diagram and increases according to the distance from the centre, being vivid away from the centre and dull near the centre.

Beef is generally darker in colour than lamb and mutton because beef muscles contain more myoglobin (Schmidt, 2002). Lambs fed a concentrate ration tend to have meat that's lighter in colour when compared to meat produced by extensive production systems (Priolo *et al*., 2002). They concluded that this phenomenon could partially be caused by a slight difference in ultimate pH (pHu), with grass fed lambs having a higher pHu.

The colour of meat is affected by the rate and extent of muscle pH decline. According to Sales (1999), normal pH decline in muscles are from approximately 7.0-7.2 to 5.5-5.7, with Lawrie (1998), noting that if this decrease in muscle pH is accomplished within 45 minutes or less after slaughter, the meat will appear pale, soft and exudative (PSE). However, if the drop in *post mortem* muscle is not too high, and a high pHu is attained, the meat will appear darker and dry (dark, firm and dry, DFD) (Lawrie, 1998).

Colour is generally not influenced by gender (Jeremiah *et al*. 1991; Vergara *et al*., 1999), however, Johnson *et al*. (2005), obtained results indicating lighter and redder muscle colours in ewe lambs. Other studies have indicated that the meat from intact males is darker in colour than castrates (Seideman *et al*., 1982). Tejeda *et al*. (2008) found no effect of live weight on meat colour, but these findings are in contrast with other authors, who reported an increase in redness (a*) with an increase in live weight because the haempigment content increases with age (Lawrie, 1998), and both lightness (L*) and yellowness (b*) decreases with increasing live weight (Teixeira *et al*., 2005). Santos-Silva *et al*. (2002), also showed a decrease in both lightness (L*), which means the meat became darker, and yellowness (b*) with an increase in slaughter weight. Martínez-Cerezo *et al*. (2005), concluded that a greater effect in meat colour is brought about by a change in diet, than either carcass weight or age.

1.4.2. Post mortem pH

The muscle pH of living animals is approximately 7.0-7.2 (Sales, 1999), while the desired ultimate pH (pHu) of meat is 5.5 (Lawrie, 1998). This reduction in pH is brought about by the anaerobic depletion of glycogen, the major energy source in muscles (Warriss, 1990). After exsanguination, all processes become anaerobic in the muscles. Anaerobic glycolysis is responsible for the breakdown of glycogen *post mortem*, resulting in the production of lactic acid and a subsequent decline in pH (Warris, 2000). This process continues until a pH value between 5.4 and 5.5 is reached. At this pH value (the iso-electric point of the principle proteins) the enzymes affecting the breakdown process becomes inactivated (Lawrie, 1998).

The pHu is determined by the amount of glycogen in the muscle at death. A high pHu is achieved in animals with a low concentration of muscle glycogen at time of slaughter (Jacob *et al*., 2005) and *vice versa*. Therefore, animals receiving a diet high in energy tend to be protected against glycogen depletion during stressful times (Priolo *et al*., 2002). Grass fed lambs will also achieve a higher pHu than lambs receiving concentrate rations. Carcasses produced by feedlot production tend to be fatter and cool down at a slower rate, leading to a more rapid rate of *post mortem* glycolysis and lowering the rate of pH decline (Lawrie, 1998; Priolo *et al*., 2002).

Consumers prefer meat with a low pHu, as it is associated with more tender and palatable meat (Gardener *et al*., 1999). A high pHu is associated with lower scores of sheep meat flavours, and higher scores for foreign flavours (Hopkins & Fogarty, 1998). Devine *et al*. (1993), reported that not flavour, juiciness nor aroma in lamb was affected by pHu, but in beef, flavour was found to be inferior in animals with a high pHu. They also found that the youngest animals in their experiment attained the lowest ultimate pH. These findings are in contrast with Bouton *et al*. (1978), who found that animal age did not significantly influence pHu, although the youngest and oldest animals in their experiments attained the highest pHu. Failla *et al*. (1996), associated greater age of lambs with lower pHu.

The effect of live weight on pHu, is a controversial issue that warrants further research. Results range from no significant influence of live weight on pHu (Martínez-Cerezo *et al*., 2005; Tejeda *et al*., 2008,), to results showing significant effects of live weight on pHu (Teixeira, 2005; Tejeda *et al*., 2008).

Johnson *et al*. (2005), showed that sex had a significant influence on pHu, with ram lambs having a higher pHu than ewes. Other studies showed an elevated pH level in ram lambs that were kept with ewe lambs until slaughtered (Bickerstaffe *et al*., 2000). Dransfield *et al*. (1990), reported that sex had no influence on pHu.

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1.4.3. Water holding capacity (WHC)

Water is generally held between the thin filaments of actin/tropomyosin and the thick myosin filament within muscles (Lawrie, 1998). The ability of meat to retain this water during the presence of external factors such as mincing, cutting and storage; is known as the water holding capacity (WHC) of meat (Sales, 1996). Water can be either ‘bound’ or ‘free’ in muscles and a total of 75% of muscles are composed of water (Lawrie, 1998).

Several authors have studied the effects of slaughter weight on the WHC of lamb meat. According to Vergara *et al*. (1999), an increase in slaughter weight is accompanied by lower values for WHC. Solomon *et al*. (1980), also found a decrease in WHC when live weight increased. Findings from Horcada (1996), indicated a decrease in WHC when slaughter weight was increased from 12 to 18 kg, but an increase above 18 kg had no effect on the WHC. A lower WHC means more water is expelled from the muscle tissue, which might suggest that meat from heavier lambs is less juicy than meat from light or medium slaughter weight lambs.

Feeding system has a significant effect on WHC, with meat from lambs produced in feedlots having a higher WHC than lambs produced on pasture (Santos-Silva *et al*., 2002). These results are in agreement with WHC variation with feeding regimes reported by Summers *et al*. (1978), who found lambs produced in a feedlot environment had a higher WHC than lambs moved from pasture to concentrate and lambs produced only on pasture.

San˜ udo *et al*. (1998), reported no significant effects of age on WHC; however, Schönfeldt *et al*. (1993), found that an increase in age lead to an increase in WHC, while results from Failla *et al*. (1996), indicated a decrease in WHC with increasing animal age. Female lambs have a greater tendency to expel water when compared to intact males (Vergara *et al*., 1999). This tendency suggests a greater initial juiciness found in female lamb meat.

The WHC of meat is influenced by the muscle pH and the rate of pH decline *post mortem* (Swatland, 1995). An elevated pHu will decrease moisture losses, thus increasing the WHC (Onyango *et al*., 1998). High temperatures can exert a loss in WHC (Lawrie, 1998).

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1.4.4. Tenderness

Meat tenderness is the most important attribute affecting meat quality (Koohmaraie *et al*., 1990; Safari *et al*., 2001). The ease of penetration (Tornberg *et al*., 1985), the ease with which meat breaks into fragments (Forrest *et al*., 1975) and the amount of residue that remains in the mouth after mastication (Tshabalala *et al*., 2003), all contribute to the impression of meat tenderness. Muscle fibres primarily affect tenderness. Older animals have coarser muscle fibres and are thus tougher, while younger animals have finer fibres (Lawrie, 1998). The connective tissue in young animals also has more soluble collagen linked to lower amounts of cross-bond connective tissue. As animal age increases, the solubility of the collagen decreases, inducing a decrease in enzyme attack susceptibility (Lawrie, 1998). Meat tenderness is influenced by an animals' growth pattern (Harper, 1999). An increase in lamb growth rate is associated with an increase in both protein degradation and protein synthesis (Sazili *et al*., 2004). Meat becomes more tender *post mortem* through either a decrease in calpastatin and/or an increase in calpain activity that regulates protein breakdown (Therkildsen *et al*., 2002). However, Sazili *et al*. (2004), found that a feed restriction early in life, accompanied by an increase in growth rate before slaughter resulted in more tender meat than animals with a fast growth rate throughout their lives. Sazili *et al*. (2004) concluded that this effect is brought about by the interaction between protein synthesis and protein degradation on calpain and calpastatin activity.

The calpain system is a pH dependant system (most effective at neutral pH) responsible for the degradation of Z-disks in skeletal muscles, resulting in tenderization. The calpain system consists of μ-calpain, m-calpain and calpain 3, which are skeletal muscle specific calpains (Koohmaraie & Geesink, 2006). The ratio of calpain: calpastatin in meat is a good indicator of calpain activity in meat, because calpastatin is responsible for the inhibition of μ-calpain and m-calpain (Ouali, 1990). The process is however pH dependant and under *post mortem* pH conditions ($pH<5.8$) the activity of the calpain system is reduced, but the effectiveness of calpastatin is reduced even more. In the presence of calcium, μ-calpain and m-calpain is activated (Kemp *et al*., 2009) and undergoes autolysis, while calpastatin requires calcium to bind and inhibit calpains (Koohmaraie & Geesink, 2006). Meat samples can be frozen at - 20°C for months and calpain and calpastatin activities can still be measured using the correct methods (Kristensen *et al*., 2006). Therefore, meat tenderness is dependent on pHu.

Devine *et al*. (1993), found that stress and nutritional status before slaughter are two major determinates for pHu. Their results showed the lowest shear force values for animals with a $pHu > 6.3$, and younger animals with a $pHu < 5.7$. Highest shear force values was attained in meat having a pHu ranging between 5.5 and 5.9. Lambs produced in feedlots have high muscle glycogen levels, which allow them to acquire a lower pHu in the face of stressors associated with slaughter procedures. Ultimate pH has a major effect on tenderness when compared to the effect of age.

Meat from heavier animals is considered to be less tender and have a more intense flavour than meat produced by light lambs (Tejeda *et al*., 2008). As weight increase, shear force values decrease (Kemp *et al*., 1976). Slaughter weight had no effect on shear force values in a study done by Solomon *et al*. (1980).

According to Field (1971) and Dransfield *et al*. (1990), wether lambs produce more tender meat than males. This effect can be ascribed to collagen accretion stimulated by testosterone. Testosterone levels increased after puberty in intact males and this results in an increase in the amount of collagen in the meat (Pommier *et al*., 1990).

Meat produced by lambs grazing pasture has higher shear force values when compared to stall-raised lambs (Font *et al.,* 2009). Priolo *et al.,* (2002), found that this difference in tenderness can be ascribed to carcass fatness. He suggested that the difference in tenderness caused by different fatness levels can either be a direct effect of fat being softer than muscle tissue, or indirectly by reduced muscle fibre shortening found in fatter carcasses. He found a positive correlation between tenderness and carcass fatness (r=0.44). Other researchers stated that the reason for pasture lambs having less tender meat might be caused by their higher levels of exercise (French *et al*., 2001). Another possibility could be the *post mortem* chilling rate, with feedlot lambs having better isolation and therefore better protection against cold shortening (Vestergaard *et al*., 2000). However, there is a group that argue that cold shortening is not so common and that the more tender meat of fatter animals is linked to the slower carcass temperature decrease resulting in a longer active calpain enzyme system and it is the latter that causes the meat to be more tender.

1.5. Chemical composition of sheep meat

The proximate analysis of lamb meat as noted by the USDA (2001) is presented in Table 2. In Table 3, the percentages moisture, protein, fat and ash of raw and cooked A2-graded carcasses are given.

Table 2 Proximate analysis of lamb meat on a natural basis (USDA, 2001).

Characteristic	Percentage edible portion (%)
Moisture	60.7
Protein	16.88
Lipid	21.59
Ash	0.88

Table 3 Mean values for the proximate analysis of South African A2 lamb meat (adapted from Van Heerden *et al*., 2007).

Nutrient analyzed	Raw (%)	Cooked (%)
Moisture	71.5	65.4
Protein	18.3	25.1
Fat	9.01	8.44
Ash	2.88	1.07

1.5.1. Moisture

Moisture in muscles is held within the myofibrils, between the myofibrils, between the myofibrils and the sarcolemma, between muscle cells and between muscle groups (Offer & Cousins, 1992). Muscles can contain approximately 75% moisture (Huff-Lonergan & Lonergan, 2005). The composition of animal muscle will vary with an increase in age, regardless of sex or species.

All the different components in muscles will increase with an increase in age, except moisture content (Lawrie, 1998). The total nitrogen will increase less and moisture will decrease with an increase in age, however, an increase in intramuscular fat and myoglobin content is also evident (Lawrie, 1998). Dransfield *et al*. (1990) and Martínez-Cerezo *et al*. (2005), explained the decrease in carcass moisture content with the existence of a negative correlation between the amount of fat and moisture. Lambuth *et al*. (1970), also showed a negative relationship between the percentage fat and moisture in the muscle. This means that as percentage fat and slaughter weight increase, a decrease in the percentage moisture will be seen.

Reducing the intake level of lambs in a feedlot will increase the moisture percentage in the muscle (Murphy *et al*., 1994). Feedlot diets are also associated with fatter carcasses, whereas leaner, free-range produced carcasses are related to higher muscle moisture content (Rowe *et al*., 1999). Carcass moisture is also increased when dietary protein levels are increased from 10 to 16% (Kemp *et al*., 1976).

1.5.2. Protein

The protein content of lean meat is approximately 20% (Huff-Lonergan & Lonergan 2005). This percentage can however, be affected by the amount of fat present, resulting in an increase of 25-30% in cooked meat, due to the moisture and fat losses experienced during cooking (Aberle *et al*., 2001). A negative correlation between the percentage fat and protein present in muscles has also been noted by Kemp *et al*. (1976) and Solomon *et al*. (1980).

Feed intake level of lambs seems to be the major determining factor influencing the chemical composition of lamb muscle. A higher intake level is associated with a higher fat percentage, resulting in a reduction in the amount of protein (Summers *et al*., 1978). However, Murphy *et al*. (1994), found no effect of intake on the percentage of protein. Kemp *et al*. (1976) and Solomon *et al*. (1980), showed lower percentages protein when lambs are slaughtered at heavier weights.

Proteins are of high biological value when consumed by animals, because of its ability to support rapid growth (Aberle *et al*., 2001). Field (1971) concluded that the presence of testosterone in bulls is responsible for their higher growth capacity and higher protein content in their meat, when compared to steers. Aberle *et al*. (2001), also found that red meat contains all the essential amino acids, in amounts nearly equivalent to human requirements, and that it is absorb easily and is highly digestible.

1.5.3. Ether extract

The ether extract of meat refers to the intramuscular fat content that is irreversibly connected to the meat, and cannot be removed prior to consumption (Raes *et al*., 2004). The ether extract consists mainly of phospholipids, cholesterol, triglycerides and small amounts of fat-soluble vitamins (Aberle *et al*., 2001). Huff-Lonergan and Lonergan (2005), noted that 5% of muscular tissue is comprised of lipids.

Rouse *et al*. (1970), showed that chemical carcass fat deposition followed the same pattern as the percentage separable fat, increasing with an increase in slaughter weight. These finding are supported by Lambuth *et al*. (1970), Kemp *et al*. (1976) and Murphy *et al*. (1994). Lambuth *et al*. (1970), studied the effect of rate of gain on the carcass composition of lambs. They found that the percentage ether extract was significantly higher ($P<0.01$) in the slower gaining group. Summers *et al*. (1978), found that a higher energy intake is accompanied by a higher percentage ether extract, resulting in a reduction in other chemical components. Kemp *et al*. (1976), also showed a decrease in the amount of ether extract when dietary protein levels were increased from 10 to 16%.

The chemical composition of muscle is influenced by sex hormones (Seideman *et al*., 1982). Not only castration, but the time of castration can influence the chemical composition, with wethers producing carcasses with higher percentages ether extract compared to intact males, this effect is more marked in lambs castrated later in life (Ouali, 1990; Destefanis *et al*., 2003). The wether carcasses in a study by Kemp *et al*. (1976), contained more moisture and protein and less ether extract than ewe carcasses. However, Summers *et al*. (1978), showed that the effect of intake level on the chemical composition of lambs, was the same for both ewe and wether meat.

Findings from several authors concluded that an increase in slaughter weight is accompanied by an increase in the percentage ether extract, and a decrease in the amount of moisture and protein (Lambuth *et al*., 1970, Kemp *et al*., 1976; Summers *et al*., 1978; Murphy *et al*., 1994).

1.6. Growth and meat production

1.6.1. Gender effect

Sex can have a detrimental effect on meat production, fat content and fatty acid profile (Okeudo & Moss, 2007). Lamb growth patterns and fat deposition is influenced by sex hormones (Seideman *et al*., 1982), giving ram lambs a growth advantage over wethers and ewes mainly because of the presence of testosterone (Schanbacher *et al*., 1980). Intact males can utilize feed more efficiently than other gender types (Crouse *et al*., 1981; Arnold & Meyer, 1988). Although the diet and sex interaction is more pronounced in ram lambs, Crouse *et al*. (1981), stated that, for rams to fully exhibit this enhanced growth over wethers and ewes, a high feed level is necessary. Therefore, the superior growth performance of ram lambs is further amplified by feedlot diets. Several factors, such as growth rate, feed conversion efficiency (FCE), meat and carcass quality, as well as body composition can be affected by sex (Rodríguez *et al*., 2008). Results reported by Notter *et* al. (1991), emphasized the fact that wethers grow faster than ewes, and rams grow faster than wethers.

Gender will influence general growth curves, for example males tend to be slightly heavier at birth than females and also have a higher growth rate (Okeudo & Moss, 2008). The following gender types have been documented in the past: entire rams, vasectomised rams, castrated rams and ewes. Castrated rams (wethers) and ewes did not differ in growth rate (P>0.05), but birth weight, growth rate, cold carcass weight and dressing out percentage (Table 4) were the same (P>0.05) for all male sex-types (entire rams, vasectomised rams and castrated rams) (Okeudo & Moss, 2008).

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Table 4 Effect of gender on different production characteristics (adapted from Okeudo & Moss, 2008).

Sex-type	Birth weight (kg)	Growth rate (g/d)	Fasted slaughter weight (kg)	Cold carcass weight (kg)	Dressing out (%)
Castrated rams	5.34	138.1	42.9	19.5	44.85
Entire rams	5.26	146.3	42.7	19.2	44.32
Vasectomised rams	4.83	145.1	42.7	18.8	43.79
Ewe	4.52	134.8	42.5	20.4	47.62
SED	0.278	4.29	0.60	0.36	0.714

Okeudo and Moss (2008), showed that ewes reached their fasted slaughter weight 27 days later than entire rams and 12 days later than castrated rams. Lawrie (1980), concluded that regardless of species, entire males will have a 5-20% higher growth rate than females. The average fasted carcass weight of all the animals (Table 4) was 42.7 kg, but ewes had heavier cold carcass weights and dressed out significantly better than all the male sex-types ($P<0.001$). Vergara *et al*. (1999), concluded that sex had no influence on carcass weight or fatness, but females did have a higher dressing percentage ($P<0.05$), smaller shrink loss ($P<0.05$) and higher conformation score ($P<0.001$).

Wethers had higher slaughter weights and dressing percentages, when compared to ewes; however, these sexes did not differ in either backfat thickness or carcass quality grade (Notter *et al*., 1991). According to Kemp *et al*. (1970), the carcass quality of ewe lambs graded higher than those of wethers. Summers *et al*. (1978), found that there was no significant difference between wethers and ewes for any of the wholesale cuts.

According to Notter *et al*. (1991), ram lambs were on average be 3.1±1.0 kg heavier at slaughter than wethers. The findings of both Kemp *et al*. (1970) and Notter *et al*. (1991), concluded that ram lambs produced heavier carcasses, at the same age, when compared to wethers, while wethers obtained a higher dressing percentage. When rams and wethers are compared at an early age (light weight), wethers tend to have a higher fat measurement; this trait is even more pronounced when weight is increased (Kemp *et al*., 1970). Some authors reported on the effect of time of castration on production (Arnold & Meyer, 1988). They concluded that delaying the age of castration decreased dressing percentages and carcass weights. It did however; increase ADG, but not significantly. These effects were probably caused by greater growth of non-carcass parts, especially the head, when the animals were still intact (Arnold & Meyer, 1988). The shank and kidney were the only two wholesale cuts affected significantly by sex ($P<0.05$ and $P<0.01$, respectively) (Kemp *et al*., 1970).

Fat distribution throughout the body is not affected by sex (Afonso & Thompson, 1996). However, Butterfield (1988), suggested that the main effect of sex on fat was through its partitioning, he concluded that, wethers and ewes have less intermuscular and mesenteric fat and more subcutaneous fat than rams, but the total fat weight in all sexes was similar. These findings are however, in contrast to those of Tejeda *et al*. (2008). They concluded that male lambs displayed smaller values for all the fat measurements (subcutaneous, intermuscular and intramuscular) and that the reason for this can be ascribed to the fact that females tend to accumulate fat from an earlier age than males. Furthermore, females have slower growth rates than their male counter parts, and therefore tend to be older than males when slaughtered.

1.6.2. Age effect

One of the major effects that chronological age plays in animal production; is the sensory attributes observed in the meat of the animal. As animal age increases, the intensity of the animal flavour in the meat increases (Sink & Caporaso, 1977). The intramuscular fat content of meat is closely related to the sensation of juiciness in cooked meat (Schönfeldt *et al*., 1993). As older animals have a higher marbling score than younger animals fed the same diet, the meat from the older animals will be juicier (Schönfeldt *et al*., 1993). Sink and Caporaso (1977), also concluded that there is a definitive effect of age on meat flavour, with older animals having a more intense flavour. When chewing the meat produced by a young animal, the first effect experienced should be watery, but a final impression of dryness is experienced due to a lower content of inter- and intramuscular fat (Schönfeldt *et al*., 1993).

An increase in age will result in a significant decrease in collagen solubility and this will increase the shear force value of the meat (Devine *et al*., 1993). Other quality traits affected by increasing age is that of pH. Older animals are more susceptible to stress and therefore a general increase in pH is associated with an increase in age (San˜ udo *et al*., 1998), although greater age have been shown to lower pH levels (Failla *et al*., 1996). Figure 1 indicates the development of different parts of the body in early and late maturing animals. This order of development is the same when animals on a low plane of nutrition (A) are compared to animals receiving a high plane of nutrition (B). The first growth curve shows the development of the head, brain, cannon and kidney fat, while growth curve 2 indicates the development of the neck, bone, tibia-fibular and intermuscular fat. The development of the thorax, muscle, femur and subcutaneous fat is shown by the third growth curve and the loin, femur, pelvis while intramuscular fat development is indicated by growth curve 4.

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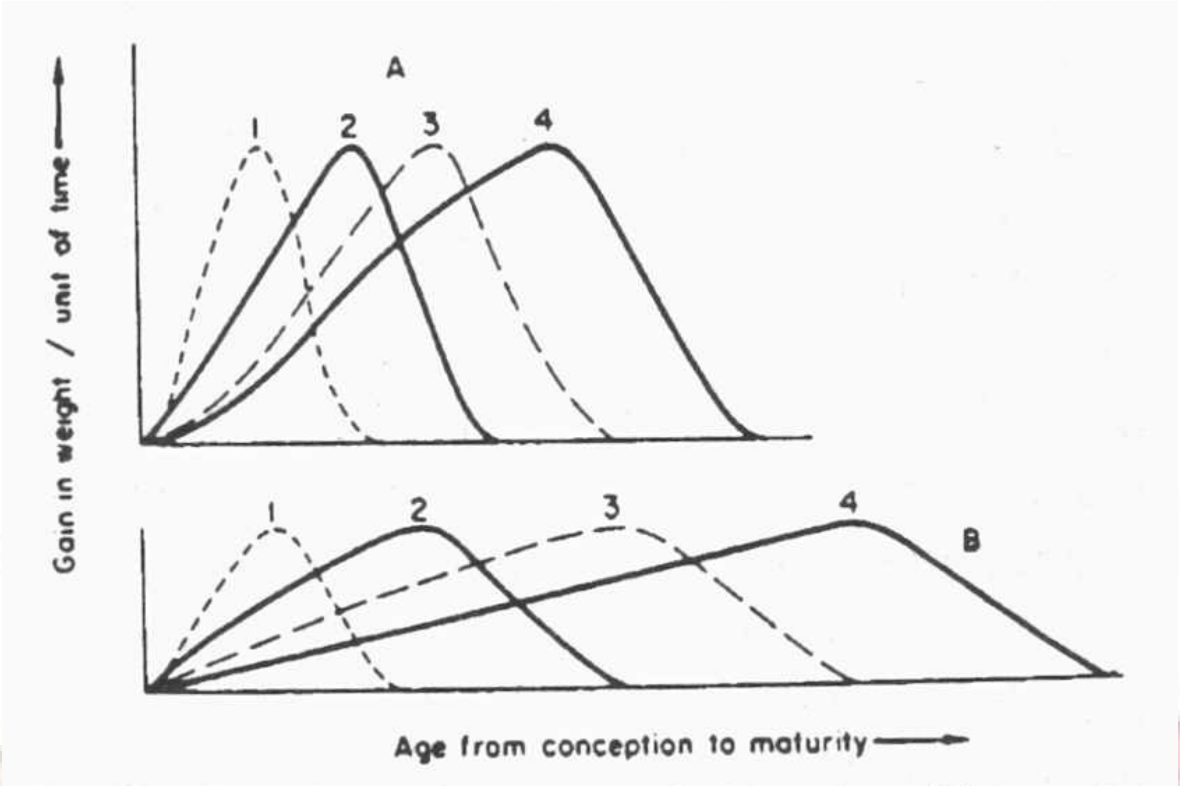

Figure 1 Development of different body tissues in early (A) and late (B) maturing animals (Lawrie, 1998).

1.6.3. Live weight effect

An increase in live weight will generally result in an increase in total carcass fat; this in turn will increase the dressing percentage of the carcass, but will decrease the retail yield (Kemp *et al*., 1970). These findings are supported by Solomon *et al*. (1980), who added that the carcass quality grades are also increased. Webb and Casey (1995), found that as the fat percentage of the carcass increased, with an accompanying increased in slaughter weight, the percentage muscle and bone decreased. Another disadvantage associated with an increase in fatness is the decrease in percentage muscle cuts (Solomon *et al*., 1980). According to Kemp *et al*., 1970), these cuts include the leg, rack, loin, breast, shoulder, and flank at the $P<0.05$ level, with the neck also decreasing at the $P<0.01$ level. These findings are however in contrast with those of Solomon *et al*. (1980), who only found a decrease in the leg cuts, and an increase in the fat cuts, such as the flank and breast. Weight will further affect the proportion of edible tissue produced by the lamb; as weight increase, the percent edible portion in the total carcass, as well as in the major wholesale cuts, will decrease (Kemp *et al*., 1970).

Fatter carcasses are produced when lambs are fed feedlot diets, these carcasses will display lower moisture, protein and ash percentages, with higher ether extract (Summers *et al*., 1978). Moisture and protein decreased with increased live weight, but the ether extract was amplified (Solomon *et al*., 1980). Lower percentage moisture was found in fatter carcasses of ewe and wether lambs when compared to leaner carcasses of intact males (Crouse *et al*., 1981; Arnold & Meyer, 1988). These authors further concluded that live weight had no effect on shear force values of the *Longissimus*, *Semimembranosus* or *Biceps femoris*. These findings are however in contrast with those of Kemp *et al*. (1976), who noted a decrease in the shear force values as live weight increased. Webb and Casey (1995), found that slaughter weight had no influence on the pH of sheep carcasses

1.7. Fat deposition

Excess nutrients that are not immediately used for ATP production are converted in the cytosol into storage forms that are readily visible under a light microscope. The largest and most important storage product is fat. Small fat droplets are present within the cytosol in various cells, and in adipose tissue, the tissue specialized for fat storage, the stored fat molecules can occupy almost the entire cytosol, where they merge to form one large fat droplet. When food is not available to provide fuel for the citric acid cycle and electron transport chain, stored glycogen and fat are broken down to release glucose and free fatty acids, respectively, which can feed the mitochondrial energy-producing machinery (Sherwood *et al*., 2000).

Fat depots are developed in lamb carcasses in the following order: mesenteric, intermuscular, omental, pelvis, renal and subcutaneous (Teixeira *et al*., 1989). The extent to which each of these depots is developed by the animal can be influenced by the various production systems and its relative importance to the animal for survival (Carrasco *et al*., 2008).

Fat composition and palatability of lambs can be affected by factors such as environmental temperature, breed and slaughter weight (Crouse *et al*., 1981). Meat colour and fat composition are two major physiochemical traits that determine meat quality and acceptability (Goliomytis *et al*., 2006; Tejeda *et al*., 2008). Although meat fat plays a major role in meat flavour (Summers *et al*., 1978; Arnold & Meyer, 1988; Notter *et al*., 1991; Priolo *et al*., 2002), it is not a significant criterion for consumers when purchasing meat (Grunert, 1997). Fat is a negative criterion for human health (Dransfield, 2001), and therefore the amount of noticeable fat on a carcass is an important trait for consumers when purchasing meat.

An important part of the total growth process in domestic animals is the growth of fat, because the role of fat in the body is to serve as an energy store, thereby enabling the animal to survive in times of periodic food scarcity and enabling them to survive during prolonged periods of underfeeding (Negussie *et al*., 2003). Body fat in total and the deposition thereof in the various fat depots affects the grading/classification of a carcass and plays a major role in deciding the optimal age to slaughter the animal (Mtenga *et al*., 1994).

The total amount of fat, and the deposition thereof amongst the various fat depots, varies remarkably throughout growth (Negussie *et al*., 2003). The partitioning of the various fat depots, along with the sequence of growth, illustrates the importance of each depot in survival of the animal, and market value of the carcass (Negussie *et al*., 2003). According to Thompson and Ball (1997), the differences observed between sheep breeds with regard to fat deposition, is associated primarily with maternal traits, more accurately, the lactation of the different breeds. The effect of sex on fat distribution is not clear; however, Butterfield (1988), reported that the lower fat content in rams, when compared to ewes and castrates, is mainly caused by a greater proportion of intermuscular fat, and a lower proportion of subcutaneous fat.

Negussie *et al*. (2003), reported that subcutaneous fat and tail fat depots are relatively late growing depots, when compared to early maturing depots such as urogenital, gut and kidney fat. Energy intake is positively related to the amount of carcass fat depots (Field *et al*., 1990). Feeding a high energy diet will decrease the firmness of lamb fat and produce fat that is more yellow in colour when compared to lambs fed a low energy diet ($P<0.01$) (Crouse *et al*., 1981). Furthermore; lambs tend to put on more fat as they reach the plateau phase of the growth curve, resulting in a higher percentage of fat trim associated with an increase in slaughter weight; accompanying this phenomenon is a decrease in the amount of bone growth as lambs reach their plateau phase (Lambuth *et al*., 1970).

Restricted feeding will result in a decrease in both mesenteric and subcutaneous fat (Murphy *et al*., 1994). Afonso & Thompson (1996), indicated that there is no difference in subcutaneous fat depths between sexes. Butterfield (1988), noted that the total proportion of subcutaneous fat is increased when lambs are castrated. Arnold & Meyer (1988), evaluated subcutaneous fat depth and kidney fat between rams, wethers and ewes and found that ewes had a higher yield grade than wethers ($P<0.001$) and wethers a better yield grade than rams ($P<0.001$), furthermore, rams had the lowest fat depth and proportion kidney fat, followed by wethers and then ewes. As an animal fattens, large amounts of fat is deposited in the kidney and pelvic regions, Lambuth *et al*. (1970), concluded that the percentage of pelvic and kidney fat will increase significantly with an increase in slaughter weight ($P<0.01$). Webb and Casey (1995), concluded that late maturing SAMM produced a lower subcutaneous fat thickness than early maturing Dorper lambs.

Sensory characteristics are influenced by intramuscular fat content (Tejeda *et al*., 2008). At the onset of chewing, an impression of wetness is produced, due to the rapid release of meat fluids, directly related to the WHC of meat (Offer & Trinick, 1983); however, sustained juiciness is mainly caused by the stimulatory effect of fat on salivation (Lawrie, 1998). The fat responsible for this effect is intramuscular fat. Castrates and ewe lambs are associated with more juicy meat than the leaner carcasses produced by intact males (Priolo *et al*., 2002). These findings are in contrast with Kemp *et al*. (1976), who found no influence of castration on the juiciness of lambs.

Lambs finished in a feedlot normally produce fatter carcasses than lambs grazing pasture; this in turn will increase the amount of intramuscular fat and improve the juiciness of the meat (Summers *et al*., 1978; Arnold & Meyer, 1988; Notter *et al*., 1991; Priolo *et al*., 2002,). By decreasing the daily intake of feedlot lambs, a decrease in the amount of intramuscular fat in the leg cuts was noticed by Murphy *et al*. (1994). Martińez-Cerezo *et al*. (2005), showed a strong correlation between slaughter age of lambs and the amount of intramuscular fat, with fat increasing linearly with an increase in age. By increasing the proportion of concentrate in the ration, the intramuscular fat also increases (Font i Furnols *et al*., 2009). Water is mainly located in muscles, and its content will decrease as the amount of intramuscular fat increases (Hoffman *et al*., 2003). The intramuscular fat content is further related to other meat characteristics such as; colour parameters and hardness (Rodríguez *et al*., 2008). Wood *et al*. (2008), found that the total lipid content of muscle (intramuscular fat) plays a major role in both the juiciness and tenderness in cooked meat. Juiciness is most affected by the amount of marbling fat present in muscles and will have a positive effect on meat quality (Wood *et al*., 2008).

1.8. Prediction of carcass composition

The sequence in animal development is characterized by two growth waves, the first wave starting at the head, spreading down to the trunk, while a secondary wave starts at the extremities of the limbs and moves upwards. Both these growth curves meet at the junction of the loin and last rib, indicating that this is the last region to develop in an animal's body (Lawrie, 1998). In lambs this region falls between the 9th and 11th rib.

Hankins and Howe (1946), developed a method to predict carcass composition by separating the bone, fat and muscle from the 8th-10th rib in beef carcasses. This is the region in beef carcasses where the two growth curves meet (Lawrie, 1998). Although the most accurate method to predict carcass composition still consists of grounding and analyzing a whole (or half) carcass, this method is seldom used because it is time consuming, expensive and difficult, it is also not economically viable as half of the carcass cannot be marketed (Paulino *et al*., 2005). The use of techniques such as X-ray computed tomography, magnetic resonance imaging (MRI), optical probes, video image analysis, total body electrical conductivity and bioelectrical impedance analysis (BIA) are methods more commonly used to predict carcass composition.

Hankins and Howe (1946), found significant correlations when predicting total fat (r=0.91), total bone (r=0.53) and total muscle (r=0.83) of a carcass by separating muscle, fat and bone and expressing them as percentages of the total cut made between the 8th and 10th rib. Paulino *et al*. (2005) observed 59.43% fat, 23.94% muscle and 16.64% bone in their dressed carcasses. These physical components was estimated by the 9th-11th rib cut when dissected, as 57.65%, 27.36% and 15.93% for fat, muscle and bone respectively, indicating almost no room for improvement when this method is used. The main production effects resulting in differences in the muscle: bone: fat ratio is feed intake level, age of maturity and slaughter weight (Kemp *et al*., 1970; Kemp *et al*., 1976; Murphy *et al*., 1994; Johnson *et al*., 2005).

Feed intake level will not affect bone weight of lambs, while a linear increase in the quantity of lean tissue within the carcass is observed with a decrease in daily DM intake (Murphy *et al*., 1994). In Table 4, the decrease, and increase in muscle, bone and fat is shown with different levels of energy intake.

Table 5 Effect of energy intake level on muscle: bone: fat ratio (adapted from Murphy *et al*., 1994).

Component %	Intake level, % of *ad libitum*		
	100	85	70
Muscle	45.10	48.19	49.12
Bone	17.69	18.30	18.13
Fat	37.21	33.51	32.75

Rouse *et al*. (1970), compared the amount of muscle, bone and fat at different live weights for lambs. They found that when live weight increased from 32 kg to 50 kg, an increase (P<0.01) in the amount of bone will be observed. These findings are supported by Kemp *et al*. (1970), who reported that, rams had significantly more bone when compared to wethers at the same slaughter weight, because of the extra fatness wethers attain during growth. Johnson *et al*. (2005), found similar results in a study done on cattle, with heifers having a higher muscle to bone ratio when compared to bulls.

The amount of lean meat and bone is negatively correlated with the amount of fat in the carcass (Lambuth *et al*., 1970). During the growth of an animal, fat deposition will increase when the plateau phase is reached; several authors who support the findings of Lambuth *et al*. (1970), added that fat deposition shows a disproportional greater increase as the animal gets heavier (Kemp *et* al., 1970; Rouse *et al*., 1970; Murphy *et al*., 1994). Figure 2 shows the effect of live weight on percentage lean, fat and bone deposition in carcasses.

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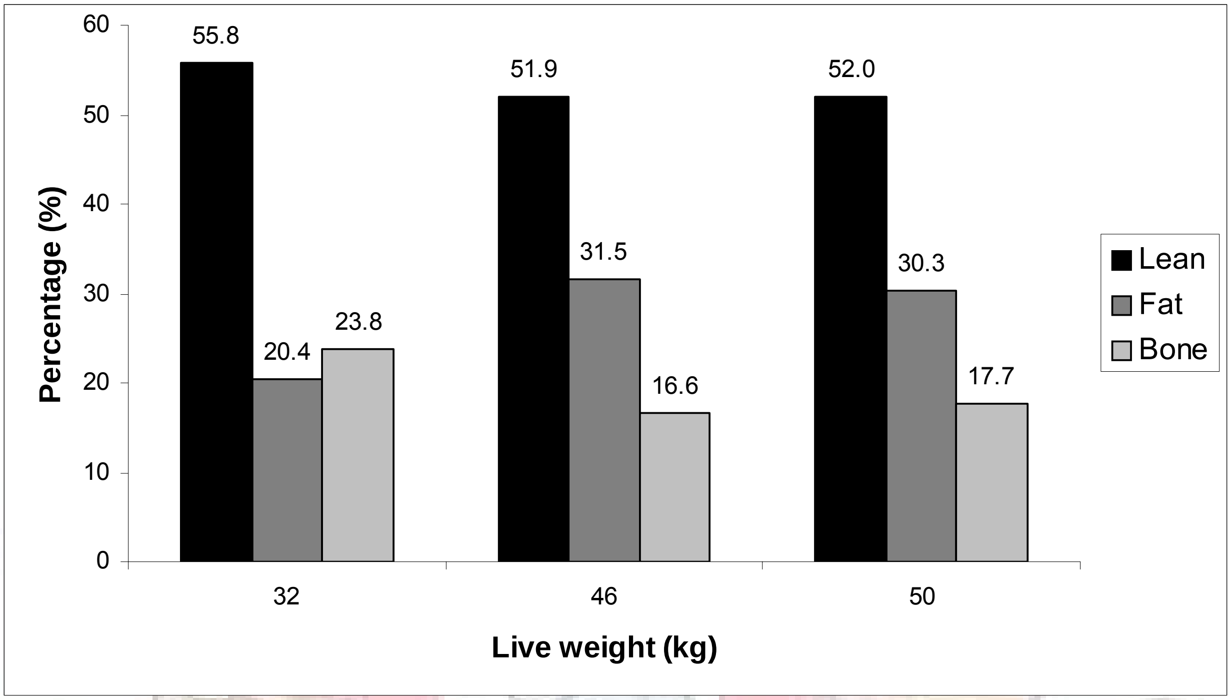

Figure 2 Percentage lean, fat and bone from lamb carcasses slaughtered at different live weights (adapted from Rouse *et al*., 1970).

When the amount of bone, lean and fat deposited in the 32 kg weight group is expressed as a percentage of the amount deposited in the 50 kg slaughter group, it is 75%, 59.6% and 37.5% respectively. These results indicate that the relative order of tissue maturation is in fact bone, muscle and then fat (Rouse *et al*., 1970).

The effect of age on the muscle: bone: fat ratio shown in

Table 6. Goliomytis *et al*. (2006), found that age had an effect (P<0.05) on all the traits. His findings showed similar results to previous researchers, where muscle and bone decreased with an increase in age, whilst an accompanying increase in the amount of fat was documented for both rams and ewes, with the exception of muscle percentage in rams. This phenomenon can be explained by the fact that ewes produce fatter carcasses than their male counter parts.

Table 6 The effect of age on carcass composition of male (M) and female (F) lambs (adapted from Goliomytis *et al*., 2006).

Age (d)	Carcass (g)		Muscle (%)		Bone (%)		Fat (%)	
	M	F	M	F	M	F	M	F
0	1905 ± 191	2091 ± 160	53.9 ± 0.6	55.9 ± 1.2	43.7 ± 0.8	41.9 ± 1.5	2.4 ± 0.7	2.2 ± 0.4
45	9013 ± 413	5754 ± 438	56.4 ± 2.8	61.2 ± 1.4	25.9 ± 1.2	27.3 ± 1.5	17.7 ± 3.7	11.5 ± 2.5
90	12729 ± 978	10853 ± 895	57.2 ± 3.0	56.1 ± 2.7	25.5 ± 0.03	25.1 ± 0.4	17.3 ± 2.9	18.9 ± 3.0
135	14637 ± 1094	10364 ± 1276	58.7 ± 1.5	59.0 ± 2.4	24.6 ± 0.5	24.5 ± 1.6	16.7 ± 1.0	16.5 ± 3.7
180	17027 ± 1539	15267 ± 1545	56.3 ± 0.9	51.6 ± 1.3	23.1 ± 0.7	21.9 ± 1.2	20.9 ± 2.3	26.4 ± 1.4
225	20893 ± 1441	18113 ± 1344	52.5 ± 0.9	51.5 ± 2.0	21.8 ± 1.0	20.9 ± 0.6	21.9 ± 0.3	27.6 ± 1.7

1.9. Conclusions

Sheep production is a major component of the South African agriculture industry (Cloete *et al*., 2004). Profitability of the small stock industry in South Africa is dominated by the total weight of lambs weaned per ewe joined (Olivier, 1999). The practice of finishing lambs in a feedlot means that lambs can be weaned earlier, allowing ewes to reach their desired condition for mating faster. Allowing lambs to be weaned off into a feedlot also allows for a higher stocking density thereby increasing the number of lambs slaughtered per annum.

Sheep numbers in South Africa decreased from 29 979 million in 1990 to 21924 million in 2007 (Department of Agriculture, 2008). The production of lean meat is negatively influenced by the increasing feed prices and the amount of lambs finished off under feedlot conditions are directly correlated to both feed- and meat prices. Increased feed- and meat prices (the current situation in South Africa) make it more profitable for farmers to finish off their lambs in feedlots (Brand *et al*., 2001).

As the information on Merino, SAMM and Dorper lambs finished off under feedlot conditions is limited, the aim of this study is to investigate the effect of finishing off these three breeds in a feedlot on their growth, retail yield, muscle: bone: fat ratios and meat quality.

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Pectora roborant cultus recti

Chapter 2

Comparative analysis of growth performance of Merino, South African Mutton Merino and Dorper lambs produced under feedlot conditions

Abstract

This study investigated the effect of feedlot production on lamb growth and slaughter characteristics. Merino, South African Mutton Merino (SAMM) and Dorper lambs were finished off under various feedlot conditions. Data from SAMM lambs were recorded during 2007 and 2008, while Dorper lambs were housed at two different feedlots (Elsenburg and Nortier) and the Merino lamb data was collected during 2007. Lambs received a balanced diet (16% protein, 10 MJ ME/kg feed) *ad libitum* and had free access to water. The lambs from each breed were divided into six groups. A group of each breed was slaughtered every three weeks until a production period of 105 days under feedlot conditions was reached. Weekly weights and feed intake was recorded to obtain daily feed intake, average daily gain (ADG) and feed conversion ratio (FCR) for each lamb. A positive ADG was achieved by the SAMM (2007) and Dorper lambs from both production sites, these results differed significantly from Merino and SAMM (2008) lambs. Feed intake for Merino lambs differed significantly from the other breeds, amplifying their weaker FCR. The FCR for the Dorper lambs housed at Elsenburg and the 2007 SAMM lambs was superior to the FCR achieved by the SAMM (2008) and Merino lambs. The SAMM (2007) lambs achieved the best FCR of all lambs. The SAMM (2007) and Dorper lambs housed at Elsenburg, achieved growth performances superior to the other production groups.

2.1. Introduction

Animal growth is defined as an increase in body weight that is achieved by both hypertrophy and hyperplasia until a mature size is reached; accompanied by changes in body conformation (Lawrie, 1998). Although genotype is the main dictator of lamb growth potential, the actual growth rate and development obtained can be manipulated by both environmental and nutritional factors (Aberle *et al*., 2001).

Feedlot diets are designed to maximize growth rate and minimize the number of days on feed (Notter *et al*., 1991). The higher energy content in concentrate rations are responsible for this effect (San˜ udo *et al*., 1998), leading to a superior average daily gain (ADG) when compared to lambs produced on pasture (Priolo *et al*., 2002). By comparing low, medium and high energy diets given to lambs in a feedlot with similar ADG, the lambs receiving the high energy diet will attain a feed conversion ratio (FCR) that is superior to those receiving the low or medium energy diet (Malik *et al.*, 1996). An animal's voluntary feed intake is limited by metabolic factors and energy intake capacity, therefore, a lamb receiving a low energy diet has to eat more than a lamb receiving a high energy diet to obtain the same growth rate (Guertin *et al.*, 1995). Differences in lamb growth rate, carcass composition and carcass fatness levels due to different levels of feeding have been reported (Santos-Silva *et al*., 2002).

In this study early- , medium- and late maturing breeds were produced under feedlot conditions. The late maturing Merino is a wool-type sheep that can produce carcasses of the highest quality, due to adaptations in their breeding strategy that enables an improved meat production capability (Olivier, 1999). The South African Mutton Merino (SAMM) is a medium maturing mutton-wool sheep (80 mutton: 20 wool) able to produce slaughter lambs with a high growth rate at an early age with excellent meat quality attributes (Cloete *et al.*, 2004). It has an excellent feed conversion ratio (Sheridan *et al*., 2003) and is therefore a popular breed in feedlot production systems (Neser *et al*., 2000). The Dorper breed is an early maturing mutton breed that produces fast growing lambs with good carcass quality characteristics (Schoeman, 2000). As the Dorper is an early maturing breed, it tends to put on more localized fat at an earlier age than late maturing breeds. This phenomenon is seen as a disadvantage that is amplified by favourable environmental conditions and intensive feeding regimes (Claasen, 2008).

Literature on the effect of feedlot diets on lamb growth and carcass characteristics under South African conditions is limited. The main aim of this study was to determine the effect of feedlot production on lamb growth parameters of Merino, SAMM and Dorper lambs.

2.2. Materials and methods

2.2.1. Lamb management

Merino, South African Mutton Merino (SAMM) and Dorper lambs were finished off under feedlot conditions and slaughtered at different ages. The SAMM lambs was born on the Langgewens Experimental farm, near Moorreesburg and transported to Elsenburg Experimental farm for the trail. The Dorper lambs was produced on Nortier Experimental farm near Lamberts Bay and housed in the feedlot on the farm and at Elsenburg Experimental farm. The Merino lambs were bought in and housed on Elsenburg Experimental farm. Dates of birth of all the lambs were recorded except for the Merino lambs. Only castrate lambs were used for the Merino data while data from both castrate and ewe lambs were used for the other production groups. All lambs were vaccinated against pulpy kidney (*Clostridia perfringes D*) and drenched against internal parasites before entering the feedlot. In 2007, 113 Merino lambs were used and data from 126 SAMM lambs were collected, while 29 and 62 Dorper lambs were finished under feedlot conditions at Elsenburg and Nortier, respectively. In 2008, data from 105 SAMM lambs were collected.

Lambs were allocated randomly to pens in the feedlot and were not subjected to an adaptation period. The lambs were fed a commercial available balanced diet (16% protein, 10MJ ME/kg feed) (Table 1 and Table 2) *ad libitum* and had free access to water. Individual lamb weights were recorded at the beginning of each week to determine average daily gain (ADG). Fresh feed was weighed and provided daily to the lambs. At the end of each week refusals were weighed back to determine feed conversion ratio (FCR). All lambs were randomly divided into six slaughter groups at the initiation of the feedlot trial. The control group was not housed in the feedlot and slaughtered at weaning. Thereafter, a group of lambs was slaughtered every 21 days. The last group was slaughtered after approximately 105-days under feedlot conditions. The amount of days in the feedlot differed for both the Merino and Dorper (produced at Nortier) lambs, due to practical arrangements during the festive season regarding the slaughter of the lambs.

Table 1 Composition of the feedlot diet.

Ingredients	As fed (g/kg)
Lucerne Hay	485.06
Maize	394.90
Cottonseed Oilcake	57.90
Calorie 3000 (Molasses powder)	25.00
Salt	10.00
Urea	5.00
Ammonium Sulphate	5.00
Slaked Lime	5.00
Ammonium Chloride	5.00
Limestone	5.00
Mono Calcium Phosphate	2.14
Total	1000.00

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Table 2 Nutrients (g/kg feed) on an as fed basis in the feedlot ration.

Nutrients	As fed
Energy	9.409 MJ/kg feed
Protein	15.999 g/kg
Total Digestible Fibre	62.997 g/kg
NDP	3.460 g/kg
RDP	12.539 g/kg
Fibre	16.090 g/kg
Acid Detergent Fibre (ADF)	20.982 g/kg
Neutral Detergent Fibre (NDF)	28.675 g/kg
Calcium (Ca)	1.473 g/kg
Phosphorus (P)	0.300 g/kg

Merino, SAMM and Dorper lambs fed at Elsenburg, were slaughtered at a commercial abattoir (Roelcor) in Malmesbury and the Dorpers produced at Nortier were slaughtered at Vredendal abattoir – also a commercial abattoir. Each slaughter group was weighed 24h prior to slaughter; this weight was used as the final slaughter weight. After being weighed lambs were loaded and transported to the abattoir with minimum stress. The transport duration was approximately 45 minutes from Elsenburg to Malmesbury, as well as from Nortier to Vredendal. Lambs were kept in lairage at the abattoirs for 18h prior to slaughter to allow sufficient resting time and water was provided *ad libitum*. Lambs were rendered unconscious by electrical stunning (200V for 4 seconds) and slaughtered using standard South African techniques. Carcass dressing and classification was completed 20 minutes *post mortem* and the carcasses were hung in random order in the cooler 1h *post mortem*. Lamb carcasses in South Africa are classified according to the Agricultural Product Standards Act No. 119 of 1990, and describe carcasses according to age and fat class. All lambs slaughtered during the trial had no permanent incisor teeth and received an A-class to describe their age. Fat classes are divided into six groups, with 0 having no fat and 6 being excessively over-fat. An A2 carcass may not have more than 4 mm, and at least 1 mm fat cover, with less than 8.5% subcutaneous fat and more than 5.6% over the loin area (National Department of Agriculture, 1990). No electrical stimulation was applied. The following day the carcasses were transported to a deboning facility and kept in a cooler for another 24h prior to sampling. Carcass weight was recorded 48h *post mortem* and excluded the kidneys and renal fat.

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2.2.2. Statistical analysis

Lambs were weighed weekly and for this purpose the weight was regressed on weighing date (in weeks) for each lamb. To obtain the ADG, the regression coefficient was divided by seven to account for the fact that weekly weights were recorded. A linear regression line was fitted to ADG, feed conversion ratio (FCR), intake and increase in weight against the amount of days housed in the feedlot. This analysis was done for each breed in both production years and sites. Regression equations computed for each variable were tested for significant differences using Proc GLM (SAS, 2006). Days housed under feedlot conditions were used as the main effect in the final model. Dressing out percentage, is defined as cold carcass weight over slaughter weight expressed as a percentage.

Results for the SAMM lambs produced at Elsenburg Experimental farm is denoted as SAMM 2007 (for the SAMM lambs produced during 2007), and SAMM 2008 (for the SAMM lambs produced during 2008). Similarly, Dorper lambs produced during 2007 at Elsenburg Experimental farm are denoted Dorper – E, whereas the Dorper lambs produced at Nortier Experimental farm during 2007 are denoted Dorper – N.

The slaughter dates for the SAMM lambs and Dorper lambs produced at Elsenburg Experimental farm were after 0, 21, 42, 63, 84 and 105 days in the feedlot. The Merino lambs were slaughtered after 0, 21, 42, 63, 77 and 98 days housed in the feedlot, while the Dorper lambs produced at Nortier Experimental farm was slaughtered after 0, 21, 42, 63, 84 and 114 days in the feedlot.

2.3. Results and discussion

The data collected for each breed, production year as well as production site are presented in Table 3 to 7. Note that feed intake and FCR is not given for the first slaughter group because weight increase and feed intake was only recorded after lambs were weaned. The values given in the following tables are least square means followed by their accompanying standard error (s.e.).

Carcass classification for the amount of days housed in the feedlot is also included in the tables. The values are percentages of the carcasses in the group that received the specific grading according to the South African classification procedures.

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Table 3 Least square means (± s.e.) depicting the effect of feedlot production on Merino lambs (2007), weaned at 109 days of age.

Parameter measured	Days in feedlot					
	0	21	42	63	77	98
ADG (g/lamb/day)		347.6 ± 27.95	314.0 ± 13.61	277.8 ± 8.61	250.6 ± 11.92	225.3 ± 7.04
Cumulative Feed Intake (kg/lamb/slaughter group)		28.8 ± 0.51	64.4 ± 1.64`	104.6 ± 2.36	121.2 ±0.83	152.9 ±1.60
FCR (kg feed intake/ kg weight gain)		2.8 ± 1.23	5.3 ± 0.25	5.9 ± 0.33	6.4 ± 0.29	7.3 ± 0.25
Slaughter age (days)	109	130	151	172	193	214
Slaughter weight (kg)	33.0 ± 1.23	36.2 ± 1.32	42.7 ± 1.36	48.8 ±1.48	49.0 ± 1.52	51.2 ± 1.39
Carcass weight (kg)	11.9 ± 0.75	15.2 ± 0.72	18.5 ± 0.73	21.2 ± 0.84	22.7 ± 1.08	23.0 ± 0.83
Dressing percentage (%)	29.0 ± 2.05	41.8 ± 0.56	43.3 ± 0.44	43.4 ± 0.87	46.3 ± 1.53	44.9 ± 0.68
Carcass classification (%)						
A0	30.00	5.60	0	0	0	0
A1	45.00	22.20	0	0	0	0
A2	25.00	72.20	89.50	57.90	33.30	5.30
A3	0	0	10.50	42.10	22.20	21.10
A4	0	0	0	0	16.70	26.25
A5	0	0	0	0	0	21.10
A6	0	0	0	0	27.80	26.25

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Table 4 Least square means (± s.e.) depicting the effect of feedlot production on SAMM lambs in 2007.

Parameter measured	Days in feedlot					
	0	21	42	63	84	105
Weaning age (days)	123.4 ± 1.58	123.4 ± 1.51	123.9 ± 1.31	117.0 ± 1.58	122.6 ± 1.79	124.0 ± 1.36
ADG (g/lamb/day)		238.1 ± 22.70	320.0 ± 10.55	287.5 ± 17.17	308.9 ± 9.28	298.4 ± 8.91
Cumulative Feed Intake (kg/lamb/slaughter group)		30.4 ± 0.98	79.5 ± 1.25	117.0 ± 2.20	167.6 ± 3.95	213.1 ± 4.64
FCR (kg feed intake/ kg weight gain)		10.3 ± 2.80	6.5 ± 0.22	7.2 ± 0.43	7.0 ± 0.21	6.9 ± 0.15
Slaughter age (days)	123.4 ± 1.58	144.4 ± 1.51	165.9 ± 1.31	180.0 ± 1.58	206.6 ± 1.79	229.0 ± 1.36
Slaughter weight (kg)	35.3 ± 1.20	41.0 ± 1.22	48.6 ± 1.29	51.0 ± 1.34	59.4 ± 1.44	67.3 ± 1.35
Carcass weight (kg)	16.1 ± 0.63	19.4 ± 0.67	23.3 ± 0.69	25.3 ± 0.76	30.2 ± 1.12	33.4 ± 0.81
Dressing percentage (%)	45.4 ± 2.00	47.1 ± 0.52	47.9 ± 0.42	49.4 ± 0.79	50.7 ± 1.13	49.6 ± 0.66
Carcass classification (%)						
A0	9.52	0	0	0	0	0
A1	14.29	4.76	0	0	0	0
A2	71.43	76.19	61.90	4.55	4.80	0
A3	4.76	19.05	38.10	18.18	9.50	0
A4	0	0	0	31.81	9.50	0
A5	0	0	0	22.73	4.80	0
A6	0	0	0	22.73	71.40	100.00

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Table 5 Least square means (± s.e.) depicting the effect of feedlot production on SAMM lambs in 2008.

Parameter measured	Days in feedlot					
	0	21	42	63	84	105
Weaning age (days)	127.7 ± 1.50	144.2 ± 1.48	144.2 ± 1.14	141.8 ± 1.30	145.1 ± 1.18	142.5 ± 1.32
ADG (g/lamb/day)		437.9 ± 20.93	348.0 ± 13.70	317.8 ± 6.73	326.4 ± 6.02	320.9 ± 7.27
Cumulative Feed Intake (kg/lamb/slaughter group)		29.1 ± 0.41	72.6 ± 1.31	114.5 ± 2.48	166.9 ± 2.36	215.3 ± 3.50
FCR (kg feed intake/ kg weight gain)		3.3 ± 0.16	4.8 ± 0.20	5.5 ± 0.13	5.9 ± 0.09	6.2 ± 0.12
Slaughter age (days)	127.7 ± 1.50	165.2 ± 1.48	186.2 ± 1.14	204.8 ± 1.30	229.1 ± 1.18	247.5 ± 1.32
Slaughter weight (kg)	31.1 ± 1.14	39.0 ± 1.35	46.9 ± 1.44	53.5 ± 1.52	59.2 ± 1.65	64.9 ± 1.56
Carcass weight (kg)	13.9 ± 0.61	17.8 ± 0.74	22.4 ± 0.77	26.2 ± 0.87	25.7 ± 0.92	28.5 ± 0.93
Dressing percentage (%)	44.2 ± 1.91	45.5 ± 0.58	47.6 ± 0.47	48.9 ± 0.90	43.2 ± 1.09	43.9 ± 0.76
Carcass classification (%)						
A0	13.00	0	0	0	0	0
A1	34.80	0	0	0	0	0
A2	52.20	94.10	25.00	11.80	0	0
A3	0	5.90	25.00	23.50	6.30	6.70
A4	0	0	31.20	11.80	18.70	20.00
A5	0	0	12.50	0	0	0
A6	0	0	6.30	52.90	75.00	73.30

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Table 6 Least square means (± s.e.) depicting the effect of feedlot production on Dorper lambs produced at Elsenburg Experimental farm (2007).

Parameter measured	Days in feedlot					
	0	21	42	63	84	105
Weaning age (days)	130.1 ± 3.37	120.4 ± 11.36	130.0 ± 3.56	132.3 ± 3.92	127.2 ± 0.80	126.2 ± 3.65
ADG (g/lamb/day)		153.7 ± 43.46	315.3 ± 43.67	296.3 ± 21.94	302.2 ± 22.84	303.3 ± 11.94
Cumulative Feed Intake (kg/lamb/slaughter group)		27.3 ± 1.09	78.5 ± 4.64	131.9 ± 11.08	174.9 ± 2.46	208.6 ± 0.72
FCR (kg feed intake/ kg weight gain)		7.0 ± 4.13	7.9 ± 1.25	7.8 ± 0.72	7.9 ± 0.98	7.0 ± 0.34
Slaughter age (days)	130.1 ± 3.37	141.4 ± 11.36	172.0 ± 3.56	195.3 ± 3.92	211.2 ± 0.80	231.2 ± 3.65
Slaughter weight (kg)	36.6 ± 3.07	36.1 ± 2.30	43.3 ± 3.65	51.3 ± 1.49	62.4 ± 4.57	61.8 ± 2.15
Carcass weight (kg)	17.4 ± 1.30	18.2 ± 1.37	21.5 ± 1.41	26.5 ± 1.78	28.3 ± 1.59	31.9 ± 1.62
Dressing percentage (%)	47.2 ± 4.10	50.2 ± 1.06	49.6 ± 0.87	51.6 ± 1.85	48.3 ± 1.45	51.5 ± 1.32
Carcass classification (%)						
A0	0	0	0	0	0	0
A1	40.00	0	0	0	0	0
A2	40.00	40.00	60.00	0	0	0
A3	20.00	60.00	40.00	0	0	0
A4	0	0	0	0	0	0
A5	0	0	0	0	0	0
A6	0	0	0	100.00	100.00	100.00

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Table 7 Least square means (± s.e.) depicting the effect of feedlot production on Dorper lambs produced at Nortier Experimental farm (2007).

Parameter measured	Days in feedlot					
	0	21	42	63	84	114
Weaning age (days)	83.1 ± 1.83	84.7 ± 2.45	82.9 ± 1.82	83.1 ± 1.83	83.0 ± 1.71	83.8 ± 1.56
ADG (g/lamb/day)		193.9 ± 40.73	247.3 ± 16.75	263.8 ± 23.44	269.1 ± 18.67	291.7 ± 7.12
Slaughter age (days)	83.1 ± 1.83	105.7 ± 2.45	124.9 ± 1.82	146.1 ± 1.83	167.0 ± 1.71	197.8 ± 156
Slaughter weight (kg)	26.6 ± 1.12	30.9 ± 1.67	35.8 ± 1.48	42.2 ± 2.34	49.3 ± 2.05	56.4 ± 1.89
Carcass weight (kg)	14.6 ± 0.92	15.0 ± 0.97	17.5 ± 1.00	22.2 ± 1.13	25.5 ± 1.81	29.5 ± 1.04
Dressing percentage (%)	54.9 ± 2.90	48.5 ± 0.75	48.8 ± 0.61	52.9 ± 1.17	51.7 ± 1.32	52.0 ± 0.85
Carcass classification (%)						
A0	0	0	0	0	0	0
A1	20.00	20.00	10.00	0	0	0
A2	80.00	80.00	90.00	60.00	0	0
A3	0	0	0	0	10.00	0
A4	0	0	0	20.00	0	0
A5	0	0	0	0	20.00	0
A6	0	0	0	20.00	70.00	100.00

The ADG for Merino lambs decreased throughout the experimental period, the Merino is a wool sheep and will not grow as efficiently under feedlot conditions as the SAMM lambs (see Table 4 and Table 5). The dressing out percentages were also lower than both SAMM and Dorper lambs (produced at Elsenburg); which further signifies that the Merino is not an efficient meat producing breed under feedlot conditions.

In South Africa, consumer demand for A2 carcasses are very high and consequently producers receive the highest profit when producing A2 carcasses. The Merino was housed for 42 days under feedlot conditions before the highest percentage of A2 carcasses was produced, while it took only 21 days under the same conditions for the SAMM and Dorper groups to achieve the same carcass. Another fact to note is that the Merino group consisted only of castrated lambs. Sex can have a detrimental effect on meat production

(Okeudo & Moss, 2008) and fat deposition (Crouse *et al.*, 1981; Seideman *et al.*, 1982), but castrate and ewe lambs did not differ (P<0.05) in either carcass quality grade or backfat thickness (Notter *et al.*, 1991).

The ADG for SAMM differed significantly between the two production years (see Table 8). This effect might have been caused by the difference in the average weaning age. The SAMM lambs produced in 2007 had an average weaning age of 122.3 ± 0.65 days and weighed on average 35.5 ± 0.46 kg, whereas the SAMM lambs produced in 2008 had an average weaning age of 140.0 ± 0.85 days and weighed 30.0 ± 0.43 kg. This indicates that the lambs produced in 2008 were older when weaned, but weighed less than the lambs produced in 2007. Therefore the number of days spent on pasture before being weaned was more for the 2008 group of lambs. This may have affected their digestive tract in a positive way, because their ADG was more enhanced upon entering into the feedlot. Another reason for the initial high ADG could be ascribed to compensatory growth by the 2008 group. Compensatory effects occurs when lambs are raised on inadequate feed and their growth potential cannot be fully exploited. Compensatory growth then takes place when an adequate feed supply is available (Kamalzadeh *et al.*, 1997). The intake of a higher quality feed, an increased feed intake, lower maintenance requirements (due to low quality feed) and a more efficient use of available nutrients, are all factors that can be associated with compensatory growth (Atti & Ben Salem, 2008).

Dressing percentages for both production years were the same for the first four slaughter groups (0, 21, 42, 63), but the last two groups in the 2008 SAMM lambs were much lower than the 2007 lambs. Dressing percentages for the 2007 group are similar to those found by Sheridan *et al*. (2003) and Cloete *et al*. (2004). SAMM lambs achieved the highest percentage of A2 graded carcasses after only 21 days under feedlot conditions. When comparing the data in Tables 3 to 7, the late maturing Merino breed graded the best carcasses in the latter stages of the experiment, while the medium maturing SAMM (2007 and 2008) had a lower percentage of A5 and A6 carcasses than the early maturing Dorper lambs (Table 6 and Table 7) in the last two slaughter groups.

The Dorper lambs housed at Elsenburg were 127.7 ± 2.15 days of age when entered into the feedlot and weighed on average 34.6 ± 1.12 kg, whereas the Dorper lambs housed at Nortier were 86.5 ± 0.72 days of age and weighed 25.9 ± 0.63 kg when entered into the feedlot. Although these differences were significant, ADG did not differ significantly between production sites. The Dorper breed is an early maturing breed, known for its excellent growth potential under both extensive and intensive feeding regimes (Schoeman, 2000). The phenomenon of Dorper lambs putting on more localized fat at an earlier age (lower live weight) than later maturing breeds is seen as a disadvantage that is amplified by intensive feeding regimes (Claasen, 2008). Results obtained for Dorper lambs in Table 6 and Table 7 support these findings, as they produced the highest percentage A5 and A6 carcasses after being housed in the feedlot for more than 84 days.

Results for ADG for each breed in both production years and sites are given in Figure 1 and Table 8. Results indicate a significant difference in ADG (g/lamb/day) between the two SAMM groups. These results can be explained by the effect of compensatory growth, as discussed above. A positive ADG was found for the SAMM (2007) and both Dorper groups, but these results differed significantly from the Merino and SAMM (2008) groups where a negative ADG was observed.

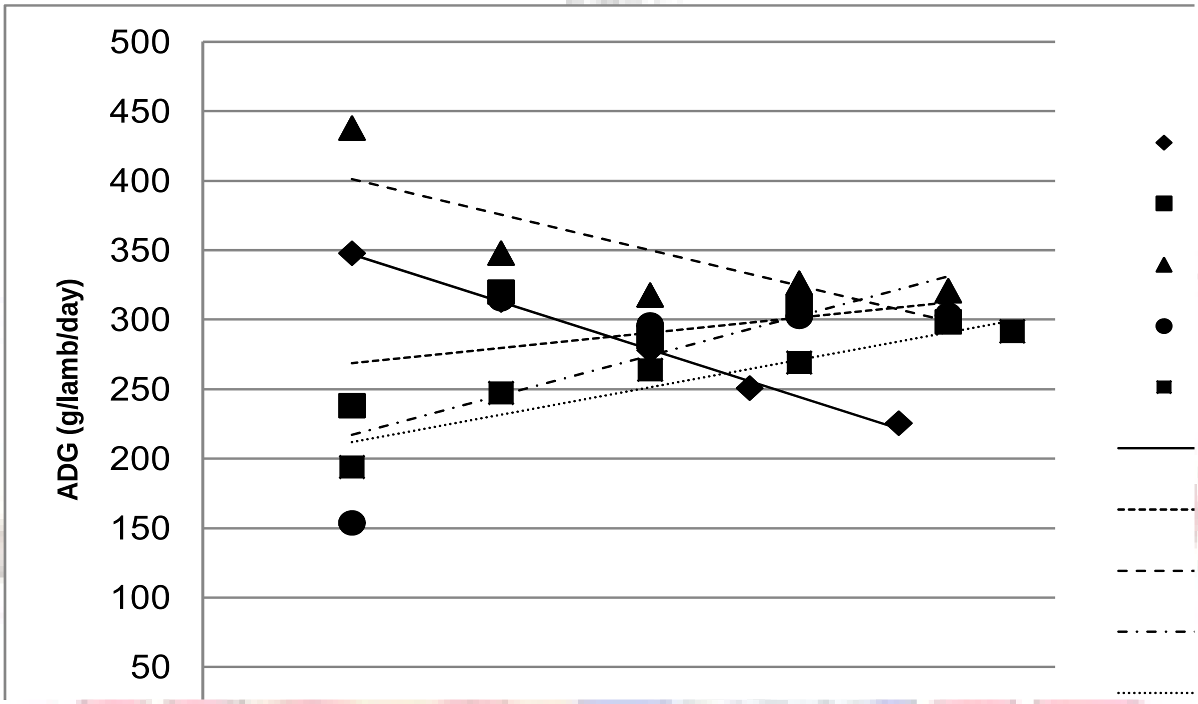

Figure 1 Regression lines between days in the feedlot and ADG for Merino, SAMM and Dorper lambs.

Table 8 Linear regression equations between days in the feedlot and ADG in Merino, SAMM and Dorper lambs.

Breed	Linear Regression Equation	R^2
Merino	$y = -1.627x + 381.0^{a}$	0.995
SAMM 2007	$y = 0.521x + 257.7^{b}$	0.298
SAMM 2008	$y = -1.216x + 426.8^{a}$	0.642
Dorper-E	$y = 1.362x + 188.3^{b}$	0.446
Dorper-N	$y = 0.939x + 192.2^{b}$	0.854

$^{a\text{-}b}$ means in a column with different superscript letters differ ($P<0.05$).

Increase in live weight (kg/day) for Dorper lambs produced at Nortier Experimental farm differed significantly from all the other production groups (Figure 2 and Table 9). No difference ($P<0.05$) was found between the two SAMM lamb groups and Dorper lambs produced at Elsenburg Experimental farm. Live weight increase between SAMM 2007 and Merino lambs differed significantly, but the Merino lambs performed similar to the SAMM 2008 and Elsenburg Dorper lambs ($P<0.05$).

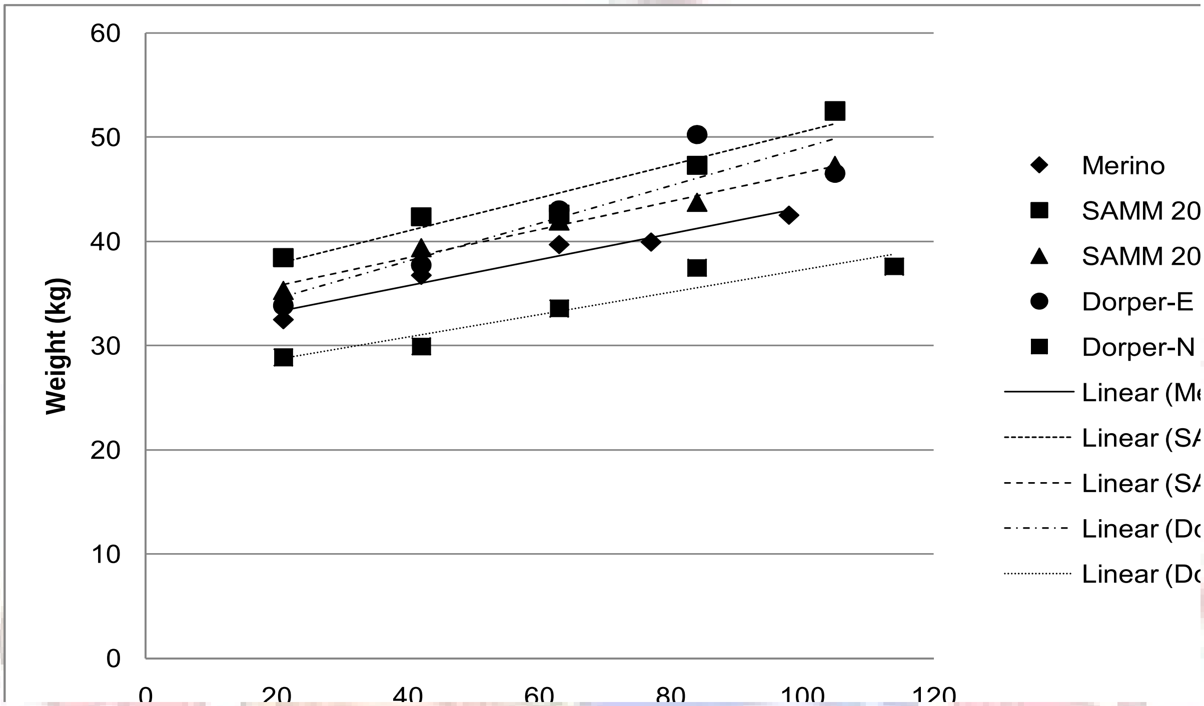

Figure 2 Regression lines between days in feedlot and increase in live weight (kg) for Merino, SAMM and Dorper lambs.

Table 9 Linear regression equations between days in feedlot and increase in live weight in Merino, SAMM and Dorper lambs.

Breed	Linear Regression Equation	R^2
Merino	$y = 0.2392x + 31.2913^{b}$	0.587
SAMM 2007	$y = 0.3087x + 34.9246^{a}$	0.705
SAMM 2008	$y = 0.3111x + 31.4575^{ab}$	0.661
Dorper-E	$y = 0.3016x + 33.198^{ab}$	0.615
Dorper-N	$y = 0.2728x + 25.4998^{c}$	0.693

$^{a-c}$ means in a column with different superscript letters differ ($P<0.05$).

Merino lambs were the only production group that differed significantly from the other groups in terms of feed intake per day (Figure 3 and Table 10). Merino lambs had the lowest feed intake per lamb for each slaughter group as well as the lowest ADG (g/lamb/day) between all production groups.

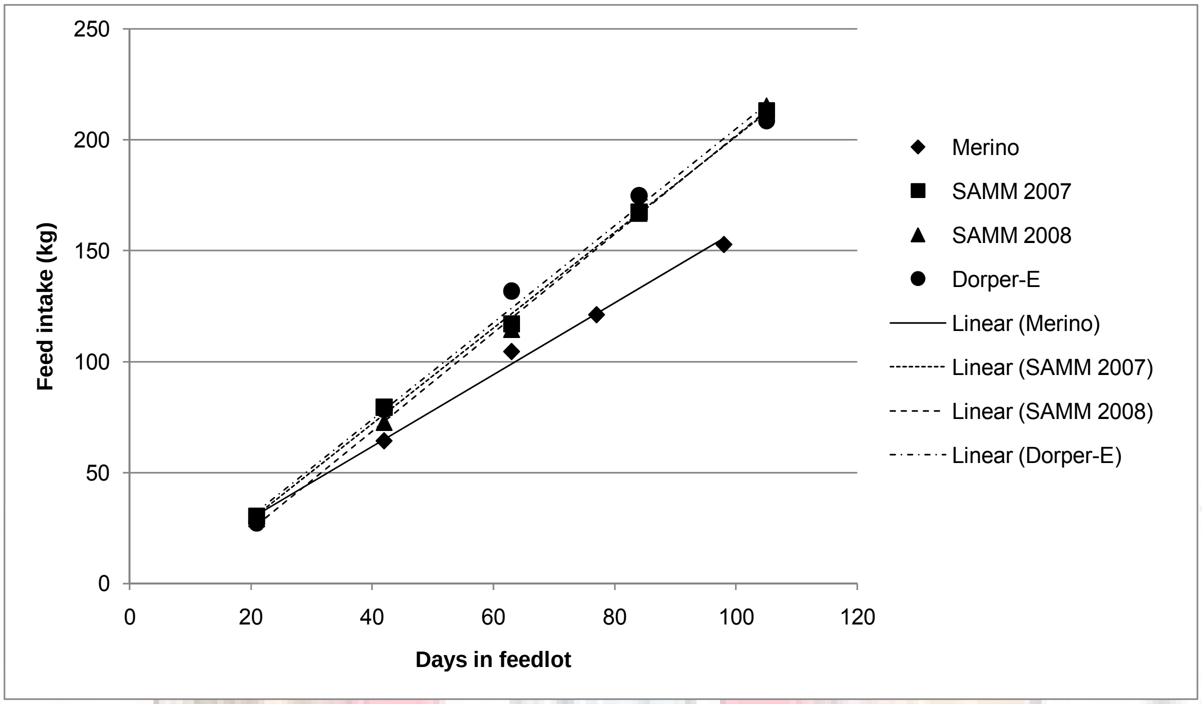

Figure 3 Regression lines between days in feedlot and feed intake (kg/day) for Merino, SAMM and Dorper lambs.

Table 10 Linear regression equations between days in feedlot and feed intake in Merino, SAMM and Dorper lambs.

Breed	Linear Regression Equation	R^2
Merino	$y = 1.619x – 3.1055^b$	0.995
SAMM 2007	$y = 2.159x – 14.474^a$	0.999
SAMM 2008	$y = 2.227x – 20.337^a$	0.998
Dorper-E	$y = 2.186x – 13.471^a$	0.992

$^{a-b}$ means in a column with different superscript letters differ ($P<0.05$).

The FCR for Dorper lambs produced at Elsenburg differed significantly from Merino and SAMM 2008, but results were similar for the Elsenburg Dorper and the SAMM 2007 group (Figure 4 and Table 11). The SAMM 2007 lambs did not differ significantly from the Merino or SAMM 2008 and Elsenburg Dorper groups. The SAMM 2007 lambs achieved a FCR superior to the other groups. These lambs maintained a negative gradient throughout the production period, indicating less feed being used for increase in live weight. Although the SAMM 2007 had the highest FCR (kg feed intake/ kg live weight increase) during the first three weeks (10.34 ± 2.80: 1) under feedlot conditions, these outlying values did not affect the results obtained.

When these values were eliminated, the regression line equation obtained is y = 0.0054x + 6.521 (R^2 = 0.211), still similar to all the other production group equations ($P<0.05$). The FCR for the Dorper lambs were relatively constant throughout their production period, while the Merino lambs attained the most unfavourable FCR of the production groups.

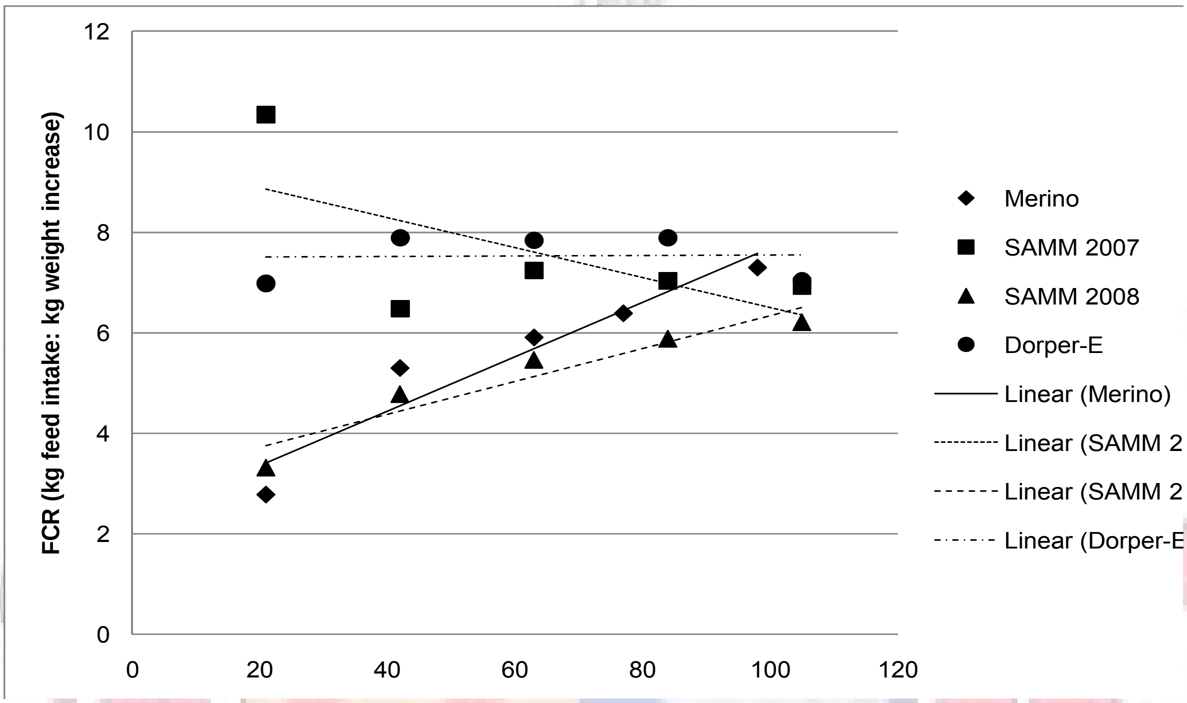

Figure 4 Regression lines between days in feedlot and FCR of Merino, SAMM and Dorper lambs.

Table 11 Linear regression equations between days in feedlot and FCR in Merino, SAMM and Dorper lambs.

Breed	Linear Regression Equation	R^2
Merino	$y = 0.0542x + 2.2732^{a}$	0.906
SAMM 2007	$y = -0.0299x + 9.485^{ab}$	0.407
SAMM 2008	$y = 0.0328x + 3.066^{a}$	0.904
Dorper-E	$y = 0.0005x + 7.496^{b}$	0.901

$^{a-b}$ means in a column with different superscript letters differ ($P<0.05$).

2.4. Conclusion

The SAMM lambs produced during 2007, and the Dorper lambs from both production sites outperformed the other groups in terms of ADG. The SAMM (2007) and Dorper lambs produced at Elsenburg also achieved the best FCR. The superior FCR of the SAMM 2007 added to the higher live weight attained by this group when compared to the other groups. Various factors that can influence the data obtained should be highlighted, such as differences in pre-weaning conditions, gender and feedlot environment. Literature on the growth performance of the different breeds under feedlot conditions is limited, and therefore further research is needed to eliminate these contributing factors, before a definite conclusion on the growth performances of Merino, SAMM and Dorper lambs under feedlot conditions can be made.

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Chapter 3

Comparative analysis of carcass composition and retail cuts of Merino, South African Mutton Merino and Dorper lambs finished off under feedlot conditions

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Abstract

Merino, South African Mutton Merino (SAMM) and Dorper lambs were finished off under various feedlot conditions. Lambs received a balanced diet (16% protein, 10 MJ ME/kg feed) *ad libitum* and had free access to water. Lambs from each breed were divided into six groups. A group of each breed was slaughtered every three weeks until a production period of 105 days under feedlot conditions was reached. Data for carcass yield and percentage retail cuts was collected to determine the effect of production days in a feedlot on these variables. Within a specific period in the feedlot the respective genders did not differ significantly for either carcass yield or percentage retail cuts. Slaughter weight, carcass weight and dressing percentage all increased significantly throughout the production period, while a decrease in the percentage head, trotters and red offal was also documented. The fatter retail cuts (thick rib, flank, prime rib and loin) increased significantly in percentage with an increase in the amount of days under feedlot conditions. A significant decrease in the percentage leaner retail cuts (raised shoulder and hind-quarters) was found when the amount of days under feedlot conditions increased. The highest profit is obtained by the prime rib, loin and hind-quarters. For the Merino and Dorper lambs these three cuts, or a combination of the three showed the highest combined percentages after 42 and 63 days under feedlot conditions, respectively. The late maturing SAMM lambs achieved the highest percentages for these three cuts after 63 and 84 days under feedlot conditions in 2007 and 2008 respectively.

3.1. Introduction

The small stock industry has shown itself to be very versatile and adaptable over the past decades with environments of practice ranging from arid, low productivity regions to fairly intensive enterprises in the pasture-cropping regions and intensive horticulture areas.(Olivier, 1999; Cloete *et al*., 2007). According to Brand *et al*. (2001) the finishing of lambs under feedlot conditions in South Africa is a practice that is being revived in the past few years as it has become more economically viable. Abattoirs also have become a more vertically integrated industry, with producers having their own abattoir and feedlot on the same premises, and often catering for their own niche market. Feedlot rations are designed to maximize growth rate of lambs and minimize the number of days on feed (Notter *et al*., 1991) whilst, the value of sheep carcasses depends on several factors, namely slaughter weight, body conformation, proportion of the main tissues (muscle, bone and fat), distribution of these tissues through the carcass and muscle yield. South African farmers have also become more aware of the value of the fifth quarter from a carcass, namely the offal, head, trotters and skin.

Although all genders are used in feedlots, ewe lambs have a slower growth rate than castrates, and castrates have a slower growth rate than entire males (Notter *et al*., 1991; Okeudo & Moss, 2008), but females will achieve higher dressing percentages ($P<0.05$) (Vergara *et* al., 1999). However, Summers *et al*. (1978), found no significant difference in percentage retail cuts produced for either castrates or ewe lambs.

The Merino is one the most popular sheep breeds in South Africa and can produce 10-15% of its own live weight as wool (Campher *et al*., 1998). In the earlier years, lamb (meat) production has been a by-product of the wool industry and at present 65-88% of the total South African income from woollen sheep is derived from meat, with contributions being even higher in the case of mutton and dual-purpose sheep (Hoon *et al*., 2000). The Merino sheep is known for its ability to produce carcasses of the highest quality (Cloete, 2007). The South African Mutton Merino (SAMM) is a dual-purpose mutton-wool sheep (80 mutton: 20 wool) known for its ability to produce slaughter lambs with a high growth rate at an early age, with good meat quality attributes (Cloete *et al*., 2004). The SAMM will adapt easily to a wide variety of environmental conditions, and its ability to efficiently convert feed into lean tissue, make it a popular breed for intensive production systems (Neser *et al*., 2000). The Dorper is well known for its meat and carcass characteristics (Schoeman, 2000). The Dorper sheep is regarded as an early maturing breed and will put on more localized fat at an earlier age (lower live weight) than later maturing breeds. This phenomenon is seen as a disadvantage that is amplified by favourable environmental conditions and intensive feeding regimes (Claasen, 2008).

Literature on the performance of these three breeds under feedlot conditions is limited and therefore the aim of this study was to determine the effect of the number of days housed in a feedlot on carcass composition and primary retail cuts in the Merino, SAMM and Dorper breeds, however, as the feedlot conditions (year, age at entry into feedlot and production site) differed between the production groups, no comparisons between breeds were made.

3.2. Materials and methods

3.2.1. Lamb management

Merino, South African Mutton Merino (SAMM) and Dorper lambs were finished off under feedlot conditions and slaughtered according to the amount of days housed in a feedlot. All breeds were housed at Elsenburg Experimental farm and a second Dorper lamb production group was housed at Nortier Experimental farm. All lambs were vaccinated against pulpy kidney (*Clostridia perfringes D*) and drenched against internal parasites before entering the feedlot. Only castrate and ewe lambs were used in the experiment and allocated randomly to pens in the feedlot, however, only castrates were used in the case of Merino lambs. The lambs were fed a balanced diet (16% protein, 10MJ ME/kg feed) (see Chapter 2 for specific ration formula) *ad libitum* and had free access to water. All lambs were randomly divided into six slaughter groups at the initiation of the feedlot trial. The control group was slaughter at weaning; they were not housed in the feedlot. Thereafter, a group of lambs was slaughtered every 21 days. The last group was slaughtered after approximately 105-days under feedlot conditions. The amount of days in the feedlot differed for both the Merino and Dorper (produced at Nortier) lambs, due to practical arrangements during the festive season regarding the slaughter of the lambs.

3.2.2. Slaughter procedures

Each slaughter group was weighed 24h prior to slaughter (lambs had free access to both feed and water until they were weighed); this weight was used as the final slaughter weight. After being weighed lambs were loaded and transported to a commercial abattoir with minimum stress. The transport duration was approximately 45 minutes from their production site to the abattoir. Lambs were kept in lairage at the abattoirs for 18h prior to slaughter to allow sufficient resting time and water was provided *ad libitum*. Lambs were rendered unconscious by electrical stunning (200V for 4 seconds) and slaughtered using standard South African techniques. Carcass dressing and classification was completed 20 minutes *post mortem* and the carcasses were hung in random order in the cooler 1h *post mortem*. Carcasses were not electrically stimulated. The following day the carcasses was transported to a deboning facility and kept in a cooler for another 24h prior to sampling.

3.2.3. Data collection

Data obtained from lambs produced in 2007 include 108 Merino lambs, 126 SAMM lambs, and 29 and 62 Dorper lambs produced at Elsenburg Experimental farm and Nortier Experimental farm, respectively. Data from 104 SAMM lambs produced in 2008 at Elsenburg was also used. The weight of different carcass components was recorded directly after slaughter. These components included the weight of the head and trotters and the combined weight of the red offal (heart, lungs, liver, spleen and oesophagus). The weights of the head, trotters and red offal were expressed as a percentage of the slaughter weight. The head was severed between the atlas and axis vertebra and the trotters were severed at the hock of each leg.

Carcasses were divided into South African primary retail cuts after 48h in the cooler. These cuts included the neck, thick rib, flank, raised shoulder, prime rib, loin and hindquarters (Van Heerden *et al*., 2007). Each carcass was divided into these cuts using the same method of separation. The individual cuts were weighed on an electronic scale to the nearest gram. The neck was removed first by a cut made at right angles to the spine, severing the neck at the seventh cervical vertebrae (the point where the neck starts bending). Removal of the hindquarters followed; this was done by loosening the flanks on the inside of the leg (following the curve of the leg muscle) to an imaginary line perpendicular to the ilium (seen from the inside of the carcass). A cut was made on this line (just missing the ilium) through the last lumbar vertebrae. The raised shoulder was removed next by pulling the front leg away from the carcass and carefully cutting through the connective tissue. The thick rib was removed by sawing through the spinal column, between the fifth and sixth ribs along an imaginary line towards the elbow joint. By sawing from the *obliquus obdominis internus* muscle parallel to the spine, and separating the spinal column perpendicular at the junction of the thoracic and lumbar vertebrae yielded the flanks, prime rib and loin, respectively.

The weights recorded for the primary retail cuts were expressed as a percentage of the cold carcass weight. The cold carcass weight was recorded 48h *post mortem*, when the core temperature of the carcasses from all breeds and slaughter groups was 3.65 ± 0.11ºC (*post mortem* pH decline and temperature will be discussed in Chapter 5). Values missing in the results are due to unforeseen arrangements and could not be documented during the trial period.

3.2.4. Statistical analysis

Differences in carcass yield and primary retail cuts between slaughter groups and the effect of gender on these variables were established by subjecting the data to Proc GLM (SAS, 2006). The full model, i.e. the effect of the amount of days housed in the feedlot and gender and the interaction among the main effects was used for the preliminary analysis. Gender was not included as a main effect for Merino lambs because only castrate lambs were used. As there were no interaction between the main effects and gender did not differ at any fixed period (days in feedlot), the final analysis only evaluated days housed under feedlot conditions as the main effect. Data from both genders were therefore pooled in the results. The values given in the following tables are least square means followed by their accompanying standard error (s.e.).

3.3. Results and discussion

Lambs of all three breeds used for this study showed no differences between genders at any fixed period (days in feedlot), therefore data from both genders were pooled. The reason why no differences were found between genders could be ascribed to the fact that these lambs had not reached sexual maturity. Results from Tables 1 to 5 show a similar trend for all breeds in terms of slaughter weight, carcass weight and dressing percentage. All three these variables increased throughout the production period, reaching their maximum values in either the last or second last slaughter groups. According to Kemp *et al*. (1970) and Solomon *et al*. (1980), an increase in live weight will generally result in an increase in total carcass fat; this in turn will increase the dressing percentage of the carcass, but will decrease the retail yield. Dressing percentage can be affected by the stomach content, the weight of the skin and the weight of the wool when live weights are recorded, with the latter particularly applicable to dual purpose (SAMM) and woollen sheep breeds (Merino)(Kirton *et al*., 1995). Although it was not the objective of this study to compare breeds, a phenomenon worth noting is the fact that the woollen Merino lambs had the lowest dressing percentage whilst the dual purpose breed (SAMM) had an intermediate dress out percentage and the mutton breed (Dorper) had the highest dress out percentage.

Table 1 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on carcass yield for Merino lambs.

	Carcass characteristic					
	Slaughter weight (kg)	Carcass weight (kg)	Dressing %	Head (%)	Trotters (%)	Red offal (%)
n	108	108	108	107	108	108
Days in feedlot						
0	30.7^{d} ± 1.41	11.8^{d} ± 0.67	38.4^{d} ± 0.51	5.5^{a} ± 0.10	2.8^{a} ± 0.07	4.2^{a} ± 0.11
21	36.2^{c} ± 1.29	14.9^{c} ± 0.61	40.9^{c} ± 0.47	5.4^{ab} ± 0.09	2.9^{a} ± 0.06	4.2^{a} ± 0.10
42	42.7^{b} ± 1.25	18.0^{b} ± 0.60	42.1^{bc} ± 0.45	5.0^{bc} ± 0.09	2.5^{b} ± 0.06	4.2^{a} ± 0.10
63	48.8^{a} ± 1.29	20.5^{ab} ± 0.61	41.9^{bc} ± 0.47	4.8^{c} ± 0.09	2.6^{b} ± 0.06	3.8^{b} ± 0.10
77	49.0^{a} ± 1.25	21.9^{a} ± 0.60	44.7^{a} ± 0.45	4.8^{c} ± 0.09	2.5^{b} ± 0.06	3.8^{b} ± 0.10
98	51.2^{a} ± 1.25	22.0^{a} ± 0.60	43.0^{ab} ± 0.45	5.2^{ab} ± 0.09	2.6^{b} ± 0.06	3.5^{b} ± 0.10
P-Value						
Days in feedlot	<0.001	<0.001	<0.001	<0.001	0.0002	<0.001

$^{a-d}$ means in a column with different superscript letters differ (P<0.05).

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Table 2 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on carcass yield for SAMM lambs produced in 2007.

	Carcass characteristic					
	Slaughter weight (kg)	Carcass weight (kg)	Dressing %	Head (%)	Trotters (%)	Red offal (%)
n	126	126	126	116	126	126
Days in feedlot						
0	35.0^{e} ± 1.23	15.7^{d} ± 0.67	44.8^{c} ± 0.42	5.0^{a} ± 0.07	2.6^{a} ± 0.07	-
21	41.2^{d} ± 1.23	19.1^{c} ± 0.67	46.3^{bc} ± 0.42	4.7^{a} ± 0.07	2.5^{ab} ± 0.07	4.7^{a} ± 0.06
42	48.2^{c} ± 1.23	22.5^{b} ± 0.67	46.6^{b} ± 0.42	4.2^{bc} ± 0.10	2.4^{ab} ± 0.07	4.4^{b} ± 0.06
63	51.6^{c} ± 1.21	24.7^{b} ± 0.66	47.7^{ab} ± 0.41	4.3^{b} ± 0.07	2.3^{bc} ± 0.07	4.5^{ab} ± 0.06
84	59.7^{b} ± 1.23	29.1^{a} ± 0.67	48.6^{a} ± 0.42	4.0^{cd} ± 0.07	2.1^{cd} ± 0.07	4.6^{ab} ± 0.06
105	67.3^{a} ± 1.26	31.6^{a} ± 0.68	47.0^{ab} ± 0.43	3.8^{d} ± 0.07	2.0^{d} ± 0.07	4.0^{c} ± 0.07
P-Value						
Days in feedlot	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

$^{a-e}$ means in a column with different superscript letters differ ($P<0.05$).

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Table 3 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on carcass yield for SAMM lambs produced in 2008.

	Carcass characteristic					
	Slaughter weight (kg)	Carcass weight (kg)	Dressing %	Head (%)	Trotters (%)	Red offal (%)
n	104	104	104	104	104	104
Days in feedlot						
0	31.2^{e} ± 1.29	13.7^{d} ± 0.68	43.5^{cd} ± 0.43	5.4^{a} ± 0.08	2.9^{a} ± 0.04	5.0^{a} ± 0.09
21	38.1^{d} ± 1.52	17.1^{c} ± 0.8	44.7^{bc} ± 0.51	5.0^{a} ± 0.10	2.5^{b} ± 0.04	4.6^{b} ± 0.10
42	46.0^{c} ± 1.56	21.4^{b} ± 0.82	46.5^{ab} ± 0.53	5.0^{a} ± 0.10	2.5^{b} ± 0.05	4.6^{b} ± 0.10
63	52.7^{b} ± 1.52	24.9^{a} ± 0.80	47.2^{a} ± 0.51	4.6^{b} ± 0.10	2.5^{b} ± 0.04	4.5^{bc} ± 0.10
84	58.2^{b} ± 1.58	24.3^{ab} ± 0.83	41.7^{d} ± 0.53	4.4^{b} ± 0.10	2.3^{c} ± 0.05	4.1^{c} ± 0.10
105	64.0^{a} ± 1.62	26.8^{a} ± 0.85	42.0^{d} ± 0.55	4.4^{b} ± 0.10	2.1^{d} ± 0.05	3.6^{d} ± 0.11
P-value						
Days in feedlot	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

$^{a-e}$ means in a column with different superscript letters differ (P<0.05).

Table 4 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on carcass yield for Dorper lambs produced at Elsenburg Experimental farm.

	Carcass characteristic					
	Slaughter weight (kg)	Carcass weight (kg)	Dressing %	Head (%)	Trotters (%)	Red offal (%)
n	29	29	29	24	29	24
Days in feedlot						
0	34.7^{c} ± 3.34	15.9^{c} ± 1.85	46.4 ± 1.18	4.9^{a} ± 0.18	2.6^{a} ± 0.06	-
21	36.5^{c} ± 3.04	18.2^{c} ± 1.69	49.8 ± 1.07	4.7^{a} ± 0.16	2.5^{ab} ± 0.05	4.7 ± 0.22
42	42.9^{bc} ± 3.04	21.0^{bc} ± 1.69	48.9 ± 1.07	-	2.3^{b} ± 0.05	4.6 ± 0.22
63	51.3^{ab} ± 3.39	26.0^{ab} ± 1.88	50.6 ± 1.19	4.2^{ab} ± 0.18	2.0^{c} ± 0.06	4.4 ± 0.25
84	62.8^{ab} ± 3.04	32.1^{a} ± 1.69	51.2 ± 1.07	3.5^{b} ± 0.16	1.9^{c} ± 0.05	4.1 ± 0.22
105	62.2^{a} ± 3.04	31.5^{a} ± 1.69	50.5 ± 1.07	3.6^{b} ± 0.16	1.8^{c} ± 0.05	4.0 ± 0.22
P-value						
Days in feedlot	<0.001	<0.001	0.098	<0.001	<0.001	0.1607

$^{a-c}$ means in a column with different superscript letters differ (P<0.05).

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Table 5 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on carcass yield for Dorper lambs produced at Nortier Experimental farm.

	Carcass characteristic					
	Slaughter weight (kg)	Carcass weight (kg)	Dressing %	Head (%)	Trotters (%)	Red offal (%)
n	62	62	62	62	62	62
Days in feedlot						
0	$25.3^{e} \pm 1.83$	$13.7^{d} \pm 1.03$	$54.0^{a} \pm 0.88$	$6.4^{a} \pm 0.13$	$2.8^{a} \pm 0.05$	$5.6^{a} \pm 0.15$
21	$29.6^{de} \pm 1.83$	$14.2^{d} \pm 1.03$	$47.8^{c} \pm 0.88$	$5.5^{b} \pm 0.13$	$2.3^{b} \pm 0.05$	$4.3^{c} \pm 0.15$
42	$35.4^{cd} \pm 1.77$	$17.0^{cd} \pm 1.00$	$48.0^{c} \pm 0.85$	$5.2^{bc} \pm 0.12$	$2.2^{bc} \pm 0.05$	$4.9^{bc} \pm 0.15$
63	$41.3^{bc} \pm 1.79$	$20.3^{bc} \pm 1.01$	$48.9^{bc} \pm 0.86$	$4.9^{cd} \pm 0.13$	$2.1^{cd} \pm 0.05$	$5.0^{ab} \pm 0.15$
84	$48.0^{ab} \pm 1.83$	$24.2^{b} \pm 1.03$	$50.4^{bc} \pm 0.88$	$4.5^{de} \pm 0.13$	$1.9^{de} \pm 0.05$	$4.9^{bc} \pm 0.15$
114	$55.4^{a} \pm 1.66$	$28.7^{a} \pm 0.94$	$51.8^{ab} \pm 0.80$	$4.0^{e} \pm 0.12$	$1.7^{e} \pm 0.05$	$4.6^{bc} \pm 0.14$
P-value						
Days in feedlot	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

$^{a-e}$ means in a column with different superscript letters differ ($P<0.05$).

The percentage head and trotters decreased throughout the production period for all the production groups. These results can be explained by the sequence of animal development, which is characterized by two growth waves, the first wave starting at the head, and spreading down the trunk, while a secondary wave starts at the extremities of the limbs and moves upwards (Lawrie, 1998). This indicates that both the head and trotters are seen as early maturing body parts of an animal, explaining why their percentages decreased as the animals progressed towards maturity.

The percentage red offal followed a similar trend as the head and trotters for the Merino, both SAMM groups and the Elsenburg Dorper group. A decrease in percentage red offal was found for these groups with an increase in the number of days spent under feedlot conditions. The decrease in the percentage of red offal found for the Nortier Dorper group (Table 5) was not as uniform as the other production groups, but the percentage red offal at weaning did differ ($P<0.05$) from the red offal after 114 days under feedlot conditions. This decrease in the percentage of the fifth quarter of the carcass can be seen as a positive for producers as more nutrients obtained from the diet is used for the growth of the higher priced edible tissue.

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The percentage primary retail cuts of the breeds examined were expressed as a percentage of the carcass weights (Tables 6 to 10).

Table 6 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on primary retail cuts of Merino lambs.

	Primary retail cuts (%)						
	Neck	Thick rib	Flank	Raised shoulder	Prime rib	Loin	Hind-quarters
n	108	108	108	108	108	108	108
Days in feedlot							
0	5.9^{a} ± 0.14	13.6^{d} ± 0.40	10.1^{b} ± 0.31	19.3^{a} ± 0.25	7.5^{b} ± 0.28	7.7^{c} ± 0.37	35.5^{a} ± 0.75
21	4.4^{b} ± 0.13	16.2^{bc} ± 0.36	8.5^{c} ± 0.28	19.0^{ab} ± 0.23	7.5^{b} ± 0.26	8.4^{bc} ± 0.34	35.6^{a} ± 0.68
42	4.5^{b} ± 0.13	14.8^{cd} ± 0.35	12.2^{a} ± 0.28	18.4^{bc} ± 0.22	8.8^{a} ± 0.25	9.9^{a} ± 0.33	34.6^{ab} ± 0.67
63	4.8^{b} ± 0.13	15.2^{bc} ± 0.36	12.7^{a} ± 0.28	18.5^{bc} ± 0.23	8.8^{a} ± 0.26	9.8^{ab} ± 0.34	33.9^{ab} ± 0.68
77	3.8^{c} ± 0.13	18.0^{a} ± 0.35	9.2^{bc} ± 0.28	18.5^{bc} ± 0.22	8.1^{ab} ± 0.25	11.1^{a} ± 0.33	32.3^{b} ± 0.67
98	5.4^{a} ± 0.13	16.6^{ab} ± 0.35	12.8^{a} ± 0.28	17.7^{c} ± 0.22	8.2^{ab} ± 0.25	10.0^{a} ± 0.33	34.0^{b} ± 0.67
P-value							
Days in feedlot	<0.0001	<0.0001	<0.0001	1.0×10^{-04}	3.0×10^{-04}	<0.0001	0.011

$^{a-d}$ means in a column with different superscript letters differ (P<0.05).

Table 7 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on primary retail cuts of SAMM lambs produced in 2007.

	Primary retail cuts (%)						
	Neck	Thick rib	Flank	Raised shoulder	Prime rib	Loin	Hind-quarters
n	126	126	126	126	126	126	126
Days in feedlot							
0	5.0^{a} ± 0.15	15.4^{ab} ± 0.39	10.3^{d} ± 0.26	17.3 ± 0.43	8.9^{ab} ± 0.21	12.2^{a} ± 0.29	29.9^{c} ± 0.50
21	5.1^{a} ± 0.15	13.2^{c} ± 0.39	10.8^{cd} ± 0.26	17.6 ± 0.42	9.2^{ab} ± 0.21	11.0^{b} ± 0.29	31.3^{bc} ± 0.50
42	3.3^{c} ± 0.15	15.5^{ab} ± 0.39	11.4^{cd} ± 0.26	17.2 ± 0.43	8.4^{b} ± 0.21	10.4^{b} ± 0.29	33.3^{ab} ± 0.50
63	3.2^{c} ± 0.15	14.7^{bc} ± 0.39	11.9^{bc} ± 0.26	16.5 ± 0.42	9.3^{a} ± 0.20	10.0^{b} ± 0.29	33.7^{a} ± 0.49
84	4.0^{b} ± 0.15	15.0^{ab} ± 0.39	12.2^{b} ± 0.26	16.7 ± 0.42	9.5^{a} ± 0.21	10.3^{b} ± 0.29	32.4^{ab} ± 0.50
105	4.3^{b} ± 0.15	16.6^{a} ± 0.40	14.6^{a} ± 0.27	16.9 ± 0.43	9.6^{a} ± 0.21	10.8^{b} ± 0.30	32.4^{ab} ± 0.51
P-value							
Days in feedlot	<0.0001	<0.0001	<0.0001	0.619	6.0 x 10^{-04}	<0.0001	<0.0001

$^{a-d}$ means in a column with different superscript letters differ (P<0.05).

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Table 8 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on primary retail cuts of SAMM lambs produced in 2008.

	Primary retail cuts (%)						
	Neck	Thick rib	Flank	Raised shoulder	Prime rib	Loin	Hind- quarters
n	104	104	104	104	104	104	104
Days in feedlot							
0	5.2^{a} ± 0.13	8.8^{b} ± 0.36	14.8^{a} ± 0.23	19.3^{a} ± 0.27	8.2^{c} ± 0.19	9.1^{d} ± 0.19	35.7^{a} ± 0.31
21	5.7^{a} ± 0.16	18.7^{a} ± 0.42	7.6^{d} ± 0.27	17.9^{bc} ± 0.32	8.1^{c} ± 0.22	8.9^{d} ± 0.23	34.4^{ab} ± 0.37
42	5.5^{a} ± 0.16	18.6^{a} ± 0.43	8.9^{c} ± 0.28	17.4^{c} ± 0.33	7.6^{c} ± 0.23	9.6^{d} ± 0.24	34.1^{bc} ± 0.38
63	5.4^{a} ± 0.16	19.3^{a} ± 0.42	9.3^{c} ± 0.27	17.9^{bc} ± 0.32	8.1^{c} ± 0.22	10.7^{c} ± 0.23	32.6^{d} ± 0.37
84	3.4^{c} ± 0.16	20.2^{a} ± 0.44	12.7^{b} ± 0.28	18.8^{ab} ± 0.33	11.6^{a} ± 0.23	13.8^{a} ± 0.24	32.8^{cd} ± 0.38
105	4.2^{b} ± 0.17	20.0^{a} ± 0.45	13.4^{b} ± 0.29	18.8^{ab} ± 0.34	10.6^{b} ± 0.24	12.4^{b} ± 0.25	34.3^{bc} ± 0.39
P-value							
Days in feedlot	<0.0001	<0.0001	<0.0001	1.0×10^{-04}	<0.0001	<0.0001	<0.0001

$^{a-d}$ means in a column with different superscript letters differ ($P<0.05$).

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Table 9 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on primary retail cuts of Dorper lambs produced at Elsenburg Experimental farm.

	Primary retail cuts (%)						
	Neck	Thick rib	Flank	Raised shoulder	Prime rib	Loin	Hind-quarters
n	29	29	29	29	29	29	29
Days in feedlot							
0	$5.1^{a} \pm 0.27$	15.1 ± 0.63	$10.1^{b} \pm 0.60$	$17.1^{a} \pm 0.41$	$8.6^{bc} \pm 0.24$	10.9 ± 0.81	$30.2^{b} \pm 1.13$
21	$4.4^{ab} \pm 0.25$	14.5 ± 0.57	$11.4^{b} \pm 0.54$	$16.9^{a} \pm 0.37$	$9.3^{b} \pm 0.22$	11.7 ± 0.74	$30.3^{ab} \pm 1.03$
42	$3.5^{b} \pm 0.25$	14.7 ± 0.57	$11.7^{b} \pm 0.54$	$17.1^{a} \pm 0.37$	$8.0^{c} \pm 0.22$	11.7 ± 0.74	$32.4^{ab} \pm 1.03$
63	$3.1^{c} \pm 0.28$	13.5 ± 0.64	$12.6^{ab} \pm 0.61$	$17.3^{a} \pm 0.41$	$9.4^{b} \pm 0.25$	10.8 ± 0.82	$34.3^{a} \pm 1.14$
84	$3.9^{bc} \pm 0.25$	13.9 ± 0.57	$14.6^{a} \pm 0.54$	$15.2^{b} \pm 0.37$	$10.5^{a} \pm 0.22$	11.0 ± 0.74	$31.4^{ab} \pm 1.03$
105	$4.1^{ab} \pm 0.25$	16.1 ± 0.57	$15.0^{a} \pm 0.54$	$16.2^{ab} \pm 0.37$	$8.7^{bc} \pm 0.22$	11.1 ± 0.74	$31.5^{ab} \pm 1.03$
P-value							
Days in feedlot	1.0×10^{-04}	0.070	<0.0001	0.002	<0.0001	0.887	0.062

$^{a-c}$ means in a column with different superscript letters differ ($P<0.05$).

Table 10 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on primary retail cuts of Dorper lambs produced at Nortier Experimental farm.

	Primary retail cuts (%)						
	Neck	Thick rib	Flank	Raised shoulder	Prime rib	Loin	Hind-quarters
n	62	62	62	62	62	62	62
Days in feedlot							
0	6.2^{a} ± 0.19	12.3^{a} ± 0.33	11.9^{c} ± 0.32	19.7^{a} ± 0.25	7.3^{d} ± 0.26	9.6^{c} ± 0.25	32.7^{a} ± 0.51
21	6.2^{a} ± 0.19	12.0^{b} ± 0.33	9.8^{c} ± 0.32	19.9^{a} ± 0.25	8.6^{c} ± 0.26	9.9^{bc} ± 0.25	32.9^{a} ± 0.51
42	6.0^{ab} ± 0.18	12.7^{bc} ± 0.32	9.7^{c} ± 0.31	19.3^{ab} ± 0.24	8.9^{bc} ± 0.25	10.8^{ab} ± 0.24	31.9^{ab} ± 0.49
63	5.3^{bc} ± 0.19	14.3^{cd} ± 0.33	8.5^{b} ± 0.32	18.3^{bc} ± 0.24	10.0^{a} ± 0.25	11.4^{a} ± 0.24	31.0^{bc} ± 0.50
84	5.3^{bc} ± 0.19	15.2^{d} ± 0.33	8.2^{ab} ± 0.32	18.2^{bc} ± 0.25	9.8^{ab} ± 0.26	11.5^{a} ± 0.25	30.3^{bc} ± 0.51
114	5.1^{c} ± 0.17	16.2^{e} ± 0.3	9.0^{a} ± 0.29	17.9^{c} ± 0.23	9.7^{ab} ± 0.23	11.4^{a} ± 0.22	29.7^{c} ± 0.46
P-value							
Days in feedlot	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

$^{a-e}$ means in a column with different superscript letters differ (P<0.05).

The percentage neck in a carcass will decrease with an increase in animal age (Kemp *et al*., 1970) as was found for SAMM 2007 (Table 7), SAMM 2008 (Table 8) and Dorper lambs produced at Nortier (Table 10). The percentage neck in all these groups differed significantly between the first and last slaughter groups. A decrease in the percentage neck was also found for Merino lambs

Results in Table 6 differed significantly between 0 and 84 days in the feedlot. The Dorper lambs produced at Elsenburg also showed a decrease in the percentage neck with an increase in feedlot production days, but these percentages did not differ significantly between the first and last slaughter groups (Table 9). These findings support the fact that the neck area is one of the first areas to develop in the sequence of animal development (Lawrie, 1998). It is only later when sheep reach sexual maturity and the secondary sexual characteristics start manifesting themselves that the rams' neck starts developing again. However, as lambs in this trial were all slaughtered before this stage, this phenomenon was not encountered.

Thick rib, flank and loin are classified as the fatter cuts in a carcass, while the hindquarters and raised shoulder is known as the leaner cuts (Solomon *et al*., 1980). According to Kemp *et al*. (1970), the prime rib is also classified as a fatter cut in sheep carcasses. An increase in age is accompanied by an increase in carcass fatness (Schönfeldt *et al*., 1993; Webb & Casey, 1995). Summers *et al*. (1978) and Solomon *et al*. (1980), indicated that as carcass fatness increased (due to an increase in age), the percentage fatter cuts in a carcass increased, while the percentage leaner cuts decreased. Results obtained for the Merino lambs (Table 6) showed similar trends as found by Summers *et al*. (1978) and Solomon *et al*. (1980), with the percentage thick rib, flank, prime rib and loin cuts increasing significantly throughout the production period, while a decrease in the percentage of raised shoulder and hind-quarters was obtained with an increase in the number of days under feedlot conditions. Similar results were found for the 2007 SAMM (Table 7) group, with the fatter cuts increasing and the leaner cuts decreasing. The only cut for the 2007 SAMM group that did not follow this trend was the raised shoulder, where no significant differences were found between the number of days under feedlot conditions for this retail cut.

The 2008 SAMM group (Table 8) achieved results similar to those described by Kemp *et al*. (1970), Summers *et al*. (1978) and Solomon *et al*. (1980). However, these results are only true for the first 84 days under feedlot conditions for this specific production group. After 84 days a significant decrease in the percentage prime rib and loin cuts was found. No significant differences were found for either the thick rib or loin cut in the Elsenburg Dorper group (Table 9). The only cut that differed ($P<0.05$) for the Elsenburg Dorper lambs between those slaughtered directly after weaning and those housed in the feedlot for 105 days was the flank. The remaining cuts showed similar trends to the other production groups, but these differences was not significant between the first and last slaughter groups. Increases in all the fatter cuts, and decreases in all the lean cuts was found for the Nortier Dorper lambs (Table 10).

The loin area is the last region of an animal to develop (Lawrie, 1998). The 2008 SAMM group were weaned at an average age of 140.0 ± 0.85 days of age, while the SAMM 2007 group was weaned at an average age of 122.3 ± 0.65 days, explaining why the 2008 SAMM lambs achieved higher percentages loin cut towards the latter stages of the trail (Table 7 and 8).

3.4. Conclusion

Gender had no effect on either carcass yield or the percentage retail cuts produced in any of the three breeds, most probably because the lambs were all slaughtered before attaining full sexual maturity. For all the production groups, the percentage head, trotters and red offal all decreased significantly with an increase in the number of days spent under feedlot conditions. This can be seen as a major advantage for farmers producing sheep through intensive feeding regimes because feed is better utilized to increase the percentage retail cuts rather than the fifth quarter of the carcass, as the highest profit is obtained from meat and not from the head, trotters or red offal. The percentage fatter retail cuts increased with an increase in age, while the leaner retail cuts decreased with increasing age for all breeds used in the experiment.

Results from Chapter 2 indicated the optimal amount of days housed under feedlot conditions (according to the percentage A2 carcasses produced) to be 42 days for Merino and Dorper lambs, and 21 days for SAMM lambs. The percentage prime rib, loin and hind-quarters, or a combination of the three, for Dorper and Merino lambs were the highest after 63 and 42 days in the feedlot, respectively. Although percentages of these cuts in both production years for the SAMM lambs were not the highest after 21 days in the feedlot, the percentage A2 carcasses produced by this breed decreased after this period (refer to Chapter 2). After assessment of the results obtained, the optimal amount of days to round off Dorper and Merino lambs in a feedlot still seems to be 42 days and 21 days for SAMM lambs.

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Chapter 4

Analysis of fat deposition and muscle: bone: fat ratio of Merino, South African Mutton Merino and Dorper lambs housed under feedlot conditions

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Abstract

The objective of this study was to determine the effect of the number of days housed in a feedlot on the various fat depots and the distribution of the main tissues (muscle, bone and fat) in Merino, South African Mutton Merino (SAMM) and Dorper lambs. Lambs received a balanced diet (16% protein, 10 MJ ME/kg feed) and had free access to water. The lambs from each breed were divided into six groups. A group of each breed was slaughtered every three weeks until a production period of approximately 105 days under feedlot conditions was reached. Carcass weight was used to express the percentage visceral and renal fat depots and an electronic calliper was used to determine subcutaneous fat depth. A three-rib cut was made on the prime rib between the 9th and 11th vertebra. This cut was dissected into muscle, bone and fat and expressed as a percentage of the total cut to predict carcass composition. Visceral and renal fat deposition increased throughout the production period for all breeds. The Dorper lambs attained the highest subcutaneous fat depth, and also produced the heaviest, but fattest carcasses. Dorper lambs had the highest dressing percentage and lowest subcutaneous fat depth for an A2 graded carcass, followed by the SAMM and then the Merino breed. Percentage muscle and bone in all carcasses decreased with an increase in the number of days under feedlot conditions, while an increase in the percentage fat was found with an increase in the number of feedlot production days. These results were the same for all the breeds.

4.1. Introduction

An important part of the total growth process in domestic animals is the deposition of fat which functions as an energy store, thereby enabling the animal to survive in times of periodic food scarcity and enabling them to survive during prolonged periods of underfeeding (Negussie *et al.,* 2003). When food is not available to provide fuel for the citric acid cycle and electron transport chain, stored glycogen and fat are broken down to release glucose and free fatty acids, which feed the mitochondrial energy-producing machinery (Sherwood, 2000).

The partitioning of the various fat depots, along with the sequence of growth, illustrates the importance of each depot in survival of the animal, and market value of the carcass (Negussie *et al.,* 2003). The order of fat depot development is mesenteric, intermuscular, omental, pelvis and renal and then subcutaneous fat (Teixeira *et al.,* 1989). Intramuscular fat is the last depot to develop (Lawrie, 1998) and plays a major role in the juiciness and tenderness of cooked meat (Wood *et al.,* 2008).

Determining carcass composition with the 3-rib cut is a method first developed by Hankins and Howe (1946), on beef carcasses and has subsequently been used on sheep as well. The sequence in animal development is characterized by two growth waves, the first wave starting at the head, then spreading down to the trunk, while a secondary wave starts at the extremities of the limbs and moves upwards. Both growth curves meet at the junction of the loin and last rib, indicating that this is the last region to develop in an animal's body (Lawrie, 1998). In lambs, this region falls between the 9th and 11th rib.

The relative order of tissue maturation is bone followed by muscle and then fat (Rouse *et al.,* 1970). The main production effects resulting in differences in the muscle: bone: fat ratio is feed intake level, age of maturity and slaughter weight (Kemp *et al.,* 1970; Kemp *et al.,* 1976; Murphy *et al.,* 1994; Johnson *et al.,* 2005). Age has a significant effect on all traits, with muscle and bone percentages decreasing with an increase in age, and the amount of fat increasing with an increase in age (Goliomytis *et al.,* 2006). An increase in slaughter weight will decrease the amount of lean and bone in a carcass, while the amount of fat will increase (Rouse *et al.,* 1970).

The objective of this study was to determine the effect of time spent in a feedlot on the size of the various fat depots and the distribution of the main tissues (muscle, bone and fat) in Merino, South African Mutton Merino (SAMM) and Dorper lambs, however, as the feedlot conditions (year, age at entry into feedlot and production site) differed between the production groups, no comparisons between breeds were made.

4.2. Materials and methods

4.2.1. Lamb management

Merino, South African Mutton Merino (SAMM) and Dorper lambs were finished off under feedlot conditions and slaughtered at different ages. The SAMM lambs was born on the Langgewens Experimental farm, near Moorreesburg and transported to Elsenburg Experimental farm for the trial. The Dorper lambs was produced on Nortier Experimental farm near Lamberts Bay and housed in the feedlot on the farm and at Elsenburg. The Merino lambs where bought in and housed on Elsenburg Experimental farm. Only castrate lambs were used for the Merino data while data from both castrate and ewe lambs were used for the other production groups. All lambs were vaccinated against pulpy kidney (*Clostridia perfringes D*) and drenched against internal parasites before entering the feedlot. In 2007, 113 Merino lambs were used and data from 126 SAMM lambs were collected, while 29 and 62 Dorper lambs were finished under feedlot conditions at Elsenburg and Nortier, respectively. In 2008, data from 104 SAMM lambs were collected.

Lambs were allocated randomly to pens in the feedlot and were not subjected to an adaptation period. The lambs were fed a commercial available balanced diet (16% protein, 10MJ ME/kg feed) (see Chapter 2 for full formulation) *ad libitum* and had free access to water. All lambs were randomly divided into six slaughter groups at the initiation of the feedlot trial. The control group was not housed in the feedlot and were slaughtered at weaning. Thereafter, a group of lambs was slaughtered every 21 days. The last group was slaughtered after approximately 105-days under feedlot conditions. The amount of days in the feedlot differed for both the Merino and Dorper (produced at Nortier) lambs, due to practical arrangements during the festive season regarding the slaughter of the lambs.

4.2.2. Slaughter procedures

Merino, SAMM and Dorper lambs fed at Elsenburg, were slaughtered at a commercial abattoir (Roelcor) in Malmesbury and the Dorpers produced at Nortier were slaughtered at Vredendal abattoir – also a commercial abattoir. Each slaughter group was weighed 24h prior to slaughter, this weight was used as the final slaughter weight. After being weighed lambs were loaded and transported to the abattoir with minimum stress. The transport duration was approximately 45 minutes from Elsenburg to Malmesbury, as well as from Nortier to Vredendal. Lambs were kept in lairage at the abattoirs for 18h prior to slaughter to allow sufficient resting time, water was provided *ad libitum*. Lambs were rendered unconscious by electrical stunning (200V for 4 seconds) and slaughtered using standard South African techniques. Carcass dressing and classification was completed 20 minutes *post mortem* and the carcasses were hung in random order in the cooler 1h *post mortem*. No electrical stimulation was applied. The following day the carcasses was transported to a deboning facility and kept in a cooler for another 24h prior to sampling.

4.2.3. Data collection

Cold carcass weight was determined 48h *post mortem*. The core temperature of the carcasses was 3.65 ± 0.11ºC. The visceral and renal fat was removed directly after slaughter, weighed and expressed as a percentage of the carcass mass. At the deboning facility, carcasses were divided into primary retail cuts. The prime rib and loin cuts from the left side of the carcass were taken for further analysis. The loin cut was used to measure the subcutaneous fat depth at the 13th rib (Gilmour *et al*., 1994) and between the 3rd and 4th lumbar vertebra (Bruwer *et al*., 1987). An electronic calliper was placed at both positions 25 mm from the midline of the spine to determine fat depth. A three-rib cut was made on the prime rib between the 9th and 11th vertebra. This cut was dissected into muscle, bone and fat and expressed as a percentage of the total cut to predict carcass composition (Hankins & Howe, 1946).

4.2.4. Statistical analysis

Differences in fat deposition and muscle: bone: fat ratios between slaughter groups and the effect of gender on these variables were established by subjecting the data to Proc GLM (SAS, 2006). The full model, i.e. the effect of the number of days housed in the feedlot and gender and the interaction among the main effects was used for the preliminary analysis. Gender was not included as a main effect for Merino lambs because only castrate lambs were used. As there were no interaction between the main effects and gender did not differ at any fixed period (days in feedlot), the final analysis only evaluated days housed under feedlot conditions as the main effect. Data from both genders were therefore pooled in the results. The values given in the following tables are least square means followed by their accompanying standard error (s.e.).

4.3. Results and discussion

As there was no interaction between the amounts of days housed under feedlot conditions and gender ($P<0.05$), least square means depicting the main effects of the parameters measured was tabulated. No differences ($P<0.05$) between gender groups were found and data for both genders were therefore pooled. The subcutaneous fat depth between the 3rd and 4th lumbar vertebra was denoted fat depth 1, and the fat depth at the 13th rib was denoted fat depth 2 in the Tables 1 to 5.

Table 1 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on fat deposition of Merino lambs (2007).

	Parameter measured				
	Carcass weight (kg)	Visceral fat (%)	Renal fat (%)	Fat depth 1 (mm)	Fat depth 2 (mm)
n	108	105	108	108	106
Days in feedlot					
0	11.8^{d} ± 0.67	1.3^{d} ± 0.36	0.9^{d} ± 0.26	0.7^{c} ± 0.50	0.6^{e} ± 0.47
21	14.9^{c} ± 0.61	1.8^{cd} ± 0.29	2.1^{c} ± 0.24	2.0^{bc} ± 0.45	2.2^{de} ± 0.43
42	18.0^{b} ± 0.60	2.8^{bc} ± 0.29	2.8^{bc} ± 0.23	2.9^{b} ± 0.47	3.4^{cd} ± 0.41
63	20.5^{ab} ± 0.61	4.0^{ab} ± 0.29	3.5^{b} ± 0.24	5.0^{a} ± 0.45	6.3^{ab} ± 0.43
77	21.9^{a} ± 0.60	4.3^{a} ± 0.29	3.6^{b} ± 0.23	5.6^{a} ± 0.44	4.8^{bc} ± 0.41
98	22.0^{a} ± 0.60	5.2^{a} ± 0.29	4.6^{a} ± 0.23	5.9^{a} ± 0.44	7.6^{a} ± 0.41
P-value					
Days in feedlot	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

$^{a-e}$ means in a column with different superscript letters differ ($P<0.05$).

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Table 2 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on fat deposition of SAMM lambs in 2007.

	Parameter measured				
	Carcass weight (kg)	Visceral fat (%)	Renal fat (%)	Fat depth 1 (mm)	Fat depth 2 (mm)
<u>n</u>	126	126	126	126	126
<u>Days in feedlot</u>					
0	$15.8^{d} \pm 0.67$	$1.2^{c} \pm 0.17$	$1.3^{e} \pm 0.24$	$3.5^{d} \pm 0.66$	$2.2^{d} \pm 0.45$
21	$19.1^{c} \pm 0.67$	$1.4^{c} \pm 0.17$	$1.7^{de} \pm 0.24$	$3.9^{d} \pm 0.66$	$3.2^{d} \pm 0.45$
42	$22.5^{b} \pm 0.67$	$2.1^{b} \pm 0.17$	$2.7^{cd} \pm 0.24$	$9.3^{b} \pm 0.66$	$5.4^{c} \pm 0.45$
63	$24.7^{b} \pm 0.66$	$2.6^{ab} \pm 0.17$	$3.4^{bc} \pm 0.24$	$5.9^{cd} \pm 0.65$	$5.9^{bc} \pm 0.44$
84	$29.1^{a} \pm 0.67$	$3.0^{a} \pm 0.17$	$4.1^{b} \pm 0.24$	$7.8^{bc} \pm 0.66$	$7.5^{b} \pm 0.45$
105	$31.6^{a} \pm 0.68$	$2.8^{ab} \pm 0.18$	$5.7^{a} \pm 0.24$	$12.3^{a} \pm 0.67$	$12.0^{a} \pm 0.46$
<u>P-value</u>					
Days in feedlot	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

$^{a\text{-}e}$ means in a column with different superscript letters differ ($P<0.05$).

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Table 3 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on fat deposition of SAMM lambs in 2008.

	Parameter measured				
	Carcass weight (kg)	Visceral fat (%)	Renal fat (%)	Fat depth 1 (mm)	Fat depth 2 (mm)
n	104	104	104	104	104
Days in feedlot					
0	13.7^{d} ± 0.68	1.3^{c} ± 0.15	1.4^{b} ± 0.22	1.6^{e} ± 0.55	1.8^{de} ± 0.55
21	17.1^{c} ± 0.80	1.1^{c} ± 0.18	1.6^{b} ± 0.26	2.8^{de} ± 0.65	1.3^{e} ± 0.65
42	21.4^{b} ± 0.82	1.8^{bc} ± 0.19	2.3^{b} ± 0.26	5.2^{cd} ± 0.67	4.1^{cd} ± 0.67
63	24.9^{a} ± 0.80	2.1^{b} ± 0.18	3.4^{a} ± 0.26	5.6^{c} ± 0.65	4.9^{c} ± 0.65
84	24.3^{ab} ± 0.83	3.1^{a} ± 0.19	3.6^{a} ± 0.26	9.8^{b} ± 0.67	9.3^{b} ± 0.67
105	26.8^{a} ± 0.85	2.6^{ab} ± 0.19	4.4^{a} ± 0.27	13.8^{a} ± 0.69	13.0^{a} ± 0.69
P-value					
Days in feedlot	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

$^{a-e}$ means in a column with different superscript letters differ ($P<0.05$).

Table 4 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on fat deposition of Dorper lambs produced at Elsenburg Experimental farm.

	Parameter measured				
	Carcass weight (kg)	Visceral fat (%)	Renal fat (%)	Fat depth 1 (mm)	Fat depth 2 (mm)
n	29	29	29	29	29
Days in feedlot					
0	15.9^{c} ± 1.85	1.4^{c} ± 0.41	0.4 ± 0.49	1.1^{c} ± 1.95	0.1^{d} ± 1.94
21	18.2^{c} ± 1.69	2.2^{bc} ± 0.38	1.2 ± 0.44	4.1^{c} ± 1.78	5.8^{cd} ± 1.76
42	21.0^{bc} ± 1.69	2.2^{bc} ± 0.38	1.1 ± 0.44	6.8^{bc} ± 1.78	5.6^{cd} ± 1.76
63	26.0^{ab} ± 1.88	3.5^{ab} ± 0.42	1.9 ± 0.49	12.3^{ab} ± 1.98	10.9^{bc} ± 1.96
84	32.1^{a} ± 1.69	4.7^{a} ± 0.38	2.6 ± 0.44	15.4^{ab} ± 1.78	15.7^{ab} ± 1.76
105	31.5^{a} ± 1.69	4.2^{a} ± 0.38	2.4 ± 0.44	18.4^{a} ± 1.78	20.4^{a} ± 1.76
P-value					
Days in feedlot	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

$^{a-d}$ means in a column with different superscript letters differ ($P<0.05$).

Due to unforeseen circumstances during the slaughter procedures of the Dorper lambs produced at Nortier, the subcutaneous fat depth could not be measured. Carcass weight, visceral fat percentage and renal fat percentages for the Nortier Dorpers are given in Table 5.

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Table 5 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on fat deposition of Dorper lambs produced at Nortier Experimental farm.

	Parameter measured		
	Carcass weight (kg)	Visceral fat (%)	Renal fat (%)
n	62	62	62
Days in feedlot			
0	$13.7^{d} \pm 1.03$	$2.0^{cd} \pm 0.36$	$1.3^{bc} \pm 0.23$
21	$14.2^{d} \pm 1.03$	$1.8^{d} \pm 0.36$	$1.1^{c} \pm 0.23$
42	$17.0^{cd} \pm 1.00$	$2.6^{bc} \pm 0.34$	$1.5^{bc} \pm 0.22$
63	$20.3^{bc} \pm 1.01$	$3.3^{bc} \pm 0.35$	$1.9^{bc} \pm 0.23$
84	$24.2^{b} \pm 1.03$	$3.8^{b} \pm 0.36$	$2.2^{b} \pm 0.23$
114	$28.7^{a} \pm 0.94$	$5.6^{a} \pm 0.32$	$3.5^{a} \pm 0.21$
P-value			
Days in feedlot	<0.0001	<0.0001	<0.0001

$^{a\text{-}d}$ means in a column with different superscript letters differ ($P<0.05$).

As was expected, the percentage visceral fat and renal fat increased throughout the production period for all breeds. The SAMM lambs from both years had approximately the same percentage of renal and visceral fat upon entering the feedlot; however the percentage renal fat at 105 days under feedlot conditions was higher than the percentage visceral fat in both production groups. These results can be explained by a study by Teixeira *et al*. (1989), who concluded that the renal fat depot developed at a later stage than the visceral fat depot. According to Arnold and Meyer (1988), castrate lambs will have a lower subcutaneous fat depth and lower percentage renal fat than ewe lambs. However, results from this study do not support their findings as gender was found to have no influence on the proportion of renal fat or the subcutaneous fat depth.

Lambs used in this experiment had little to no movement for exercise, and received a high energy diet. These factors contributed to the increasing percentage visceral and renal fat deposition. Crouse *et al*. (1981), also observed a higher fat deposition in lambs receiving a high energy diet.

Dorper lambs produced at Elsenburg had the highest subcutaneous fat depth of all breeds. According to Lawrie (1998), this phenomenon can be explained through the early maturing characteristics of the breed, which tend to gain fat readily. This effect is further amplified by intensive feeding regimes (Claasen, 2008). The late maturing SAMM breed tends to put on subcutaneous fat at a slower rate (Neser *et al*., 2000) than the early maturing Dorper breed, but the Merino is a leaner breed, when compared to the SAMM, and does not reach the high fat levels of the SAMM (Table 1, 2 and 3). Results also show that the Dorper lambs rendered heavier but fatter carcass than the SAMM, and the SAMM lambs produced heavier but fatter carcasses than the Merino lambs. These effects were found after only 21 days under feedlot conditions, supporting the findings of Cloete (2002).

In South Africa A2 graded carcasses earn producers the highest profit. According to the Agricultural Product Standards Act No. 119 of 1990, an A2 carcass may not have more than 4 mm and at least 1 mm fat cover with less than 8.5% subcutaneous fat and more than 5.6% over the loin area (National Department of Agriculture, 1990). In Chapter 2 carcass classifications was given for the various breeds. The Merino and both Dorper production groups produced the highest percentage A2 carcasses after 42 days in the feedlot, while the SAMM lambs from both years achieved the highest percentage A2 carcasses after 21 days in the feedlot. Carcass characteristics of A2 graded carcasses from the breeds used is given in Table 6.

Table 6 Means (± s.e.) for various carcass characteristics of A2 graded carcasses of Merino, SAMM and Dorper lambs.

	Merino	SAMM	Dorper
Slaughter weight (kg)	42.7 ± 0.81	39.5 ± 0.64	36.0 ± 1.51
Carcass weight (kg)	18.2 ± 0.41	18.0 ± 0.33	17.2 ± 0.82
Dressing percentage (%)	42.5 ± 0.28	45.5 ± 0.21	47.9 ± 0.86
Fat depth 1 (mm)	3.4 ± 0.19	2.7 ± 0.17	2.9 ± 0.59
Fat depth 2 (mm)	3.5 ± 0.28	4.3 ± 0.36	2.6 ± 0.66

Results from Table 6 show that an A2 Dorper carcasses had the lowest slaughter weight of all three breeds, but the highest dressing percentage and lowest subcutaneous fat depth at both sites. According to Kirton *et al*. (1995), dressing percentage is known to increase with an animals' degree of fatness and slaughter weight; however slaughter weight can be influenced by the content of the digestive tract (Cloete, 2002). Another contributing factor to the lower dressing percentages found for Merino and SAMM lambs could be due to their wool production capabilities, this was however not taken into consideration for the trial. These findings support the fact that the Dorper is an early maturing breed compared to the medium and late maturing Merino and SAMM breeds, respectively. Body fat in total and the deposition thereof in the various fat depots affects the grading/classification of a carcass and plays a major role in deciding the optimal age to slaughter the animal (Mtenga *et al*., 1994).

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Although the most accurate method to predict carcass composition still consists of grounding and analyzing a whole (or half) carcass, this method is seldom used because it is time consuming, expensive and difficult, it is also not economically viable as half of the carcass cannot be marketed (Paulino *et al*., 2005).

Hankins and Howe (1946), found significant correlations when predicting total fat (r=0.91), total bone (r=0.53) and total muscle (r=0.83) of a beef carcass by separating muscle, fat and bone and expressing them as percentages of the total cut made between the 8th and 10th rib. Paulino *et al*. (2005) observed 59.43% fat, 23.94% muscle and 16.64% bone in their dressed carcasses. These physical components was estimated by the 9th-11th rib cut when dissected, as 57.65%, 27.36% and 15.93% for fat, muscle and bone respectively, indicating almost no room for improvement when this method is used. The main production effects resulting in differences in the muscle: bone: fat ratio is feed intake level, age of maturity and slaughter weight (Kemp *et al*., 1970; Kemp *et al*., 1976; Murphy *et al*., 1994; Johnson *et al*., 2005). The relative order of tissue development is bone, followed by muscle and then fat (Rouse *et al*., 1970). Results for the distribution of the main tissues through the carcass, as predicted by the 9th – 11th rib cut, are given in Tables 7 to 11.

Table 7 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the distribution of the main tissues (muscle, bone and fat) in Merino lambs (n=108) as predicted by the 9th-11th rib cut.

	Parameter measured			
	Carcass weight (kg)	Muscle (%)	Bone (%)	Fat (%)
<u>Days in feedlot</u>				
0	11.8^{d} ± 0.67	52.8^{a} ± 1.38	30.2^{a} ± 1.15	16.4^{d} ± 1.77
21	14.9^{c} ± 0.61	48.0^{ab} ± 1.26	23.9^{b} ± 1.05	27.6^{c} ± 1.61
42	18.0^{b} ± 0.60	45.2^{b} ± 1.22	22.4^{bc} ± 1.02	32.3^{bc} ± 1.57
63	20.5^{ab} ± 0.61	43.5^{bc} ± 1.26	21.1^{bc} ± 1.05	34.9^{ab} ± 1.61
77	21.9^{a} ± 0.60	38.3^{c} ± 1.22	20.1^{bc} ± 1.02	41.4^{a} ± 1.57
98	22.0^{a} ± 0.60	39.0^{c} ± 1.22	19.4^{c} ± 1.02	40.5^{a} ± 1.57
<u>P-value</u>				
Days in feedlot	<.0001	<.0001	<.0001	<.0001

$^{a\text{-}d}$ means in a column with different superscript letters differ (P<0.05).

Table 8 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the distribution of the main tissues (muscle, bone and fat) in SAMM lambs produced in 2007 (n=126) as predicted by the 9th-11th rib cut.

	Parameter measured			
	Carcass weight (kg)	Muscle (%)	Bone (%)	Fat (%)
<u>Days in feedlot</u>				
0	15.8^{d} ± 0.67	49.9^{a} ± 1.01	22.9^{a} ± 0.75	26.2^{d} ± 1.39
21	19.1^{c} ± 0.67	47.8^{a} ± 1.01	21.4^{a} ± 0.74	30.7^{d} ± 1.38
42	22.5^{b} ± 0.67	41.5^{b} ± 1.01	20.1^{a} ± 0.75	38.4^{c} ± 1.39
63	24.7^{b} ± 0.66	37.9^{bc} ± 0.99	16.6^{b} ± 0.73	45.0^{b} ± 1.36
84	29.1^{a} ± 0.67	36.0^{c} ± 1.01	16.4^{b} ± 0.74	47.6^{ab} ± 1.38
105	31.6^{a} ± 0.68	31.3^{d} ± 1.03	15.1^{b} ± 0.76	53.4^{a} ± 1.41
<u>P-value</u>				
Days in feedlot	<.0001	<.0001	<.0001	<.0001

$^{a-d}$ means in a column with different superscript letters differ (P<0.05).

Samples of the 3-rib cut for the SAMM lambs housed for 21 days in the feedlot during the 2008 production year could not be measured (due to unforeseen circumstances at the time) and are therefore not tabulated.

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Table 9 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the distribution of the main tissues (muscle, bone and fat) in SAMM lambs produced in 2008 (n=87) as predicted by the 9^{th}-11^{th} rib cut.

	Parameter measured			
	Carcass weight (kg)	Muscle (%)	Bone (%)	Fat (%)
Days in feedlot				
0	13.7^{d} ± 0.68	52.4^{a} ± 1.51	26.7^{a} ± 0.84	20.8^{b} ± 1.77
42	21.4^{b} ± 0.82	40.6^{b} ± 1.84	17.8^{b} ± 1.02	41.6^{a} ± 2.15
63	24.9^{a} ± 0.80	37.5^{b} ± 1.79	17.0^{b} ± 0.99	45.5^{a}± 2.10
84	24.3^{ab} ± 0.83	35.5^{b} ± 1.86	17.4^{b} ± 1.03	47.1^{a} ± 2.18
105	26.8^{a} ± 0.85	34.5^{b} ± 1.92	16.7^{b} ± 1.06	48.8^{a} ± 2.24
P-value				
Days in feedlot	<.0001	<.0001	<.0001	<.0001

$^{a-d}$ means in a column with different superscript letters differ ($P<0.05$).

Table 10 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the distribution of the main tissues (muscle, bone and fat) in Dorper lambs produced at Elsenburg Experimental farm (n=29) as predicted by the 9^{th}-11^{th} rib cut.

	Parameter measured			
	Carcass weight (kg)	Muscle (%)	Bone (%)	Fat (%)
Days in feedlot				
0	15.9^{c} ± 1.85	51.3^{a} ± 2.23	23.8 ± 2.28	24.5^{b} ± 2.72
21	18.2^{c} ± 1.69	47.6^{ab} ± 2.03	19.4 ± 2.07	32.7^{b} ± 2.48
42	21.0^{bc} ± 1.69	45.9^{ab} ± 2.03	23.2 ± 2.07	30.4^{b} ± 2.48
63	26.0^{ab} ± 1.88	38.2^{bc} ± 2.26	14.1 ± 2.31	47.5^{a} ± 2.76
84	32.1^{a} ± 1.69	29.4^{c} ± 2.03	13.4 ± 2.07	57.2^{a} ± 2.48
105	31.5^{a} ± 1.69	33.4^{c} ± 2.03	15.8 ± 2.07	50.2^{a} ± 2.48
P-value				
Days in feedlot	<.0001	<.0001	0.0078	<.0001

$^{a-c}$ means in a column with different superscript letters differ ($P<0.05$).

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Table 11 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the distribution of the main tissues (muscle, bone and fat) in Dorper lambs produced at Nortier Experimental farm (n=61) as predicted by the 9th-11th rib cut.

	Parameter measured			
	Carcass weight (kg)	Muscle (%)	Bone (%)	Fat (%)
Days in feedlot				
0	13.7^{d} ± 1.03	58.0 ± 1.91	31.0^{ab} ± 1.78	11.0^{c} ± 2.02
21	14.2^{d} ± 1.03	53.2 ± 1.91	34.3^{a} ± 1.78	10.9^{c} ± 2.02
42	17.0^{cd} ± 1.00	56.7 ± 1.96	29.0^{ab} ± 1.83	14.4^{bc} ± 2.07
63	20.3^{bc} ± 1.01	58.7 ± 1.87	27.5^{ab} ± 1.75	13.9^{bc} ± 1.98
84	24.2^{b} ± 1.03	52.7 ± 1.91	26.2^{bc} ± 1.78	19.7^{ab} ± 2.02
114	28.7^{a} ± 0.94	51.0 ± 1.73	19.6^{c} ± 1.62	28.0^{a} ± 1.84
P-value				
Days in feedlot	<.0001	0.0147	<.0001	<.0001

$^{a\text{-}d}$ means in a column with different superscript letters differ (P<0.05).

The percentage of lean meat and bone is negatively correlated with the percentage of fat in the carcass (Lambuth *et al*., 1970). During the growth of an animal, fat deposition will increase when the plateau phase of the sigmodial growth curve is reached (Lambuth *et al*., 1970). Several authors who support these findings added that fat deposition shows a disproportional greater increase as the live weight of the animal increases (Kemp *et* al., 1970; Rouse *et al*., 1970; Murphy *et al*., 1994). Results from Tables 7 to 11, show similar results as described by these authors, with the percentage bone and muscle decreasing throughout the production period. As described by Lambuth *et al*. (1970), the percentage fat was negatively correlated with the percentage muscle and bone, with the percentage muscle and bone decreasing throughout the production period and the percentage fat increasing throughout the production period. The only group for which these effects were marginal was the Nortier Dorpers, but significant decreases in the muscle and bone, and a significant increase in the amount of fat was still observed. Table 12 shows the various linear regression equations for the decrease in bone and muscle and increase in fat percentage.

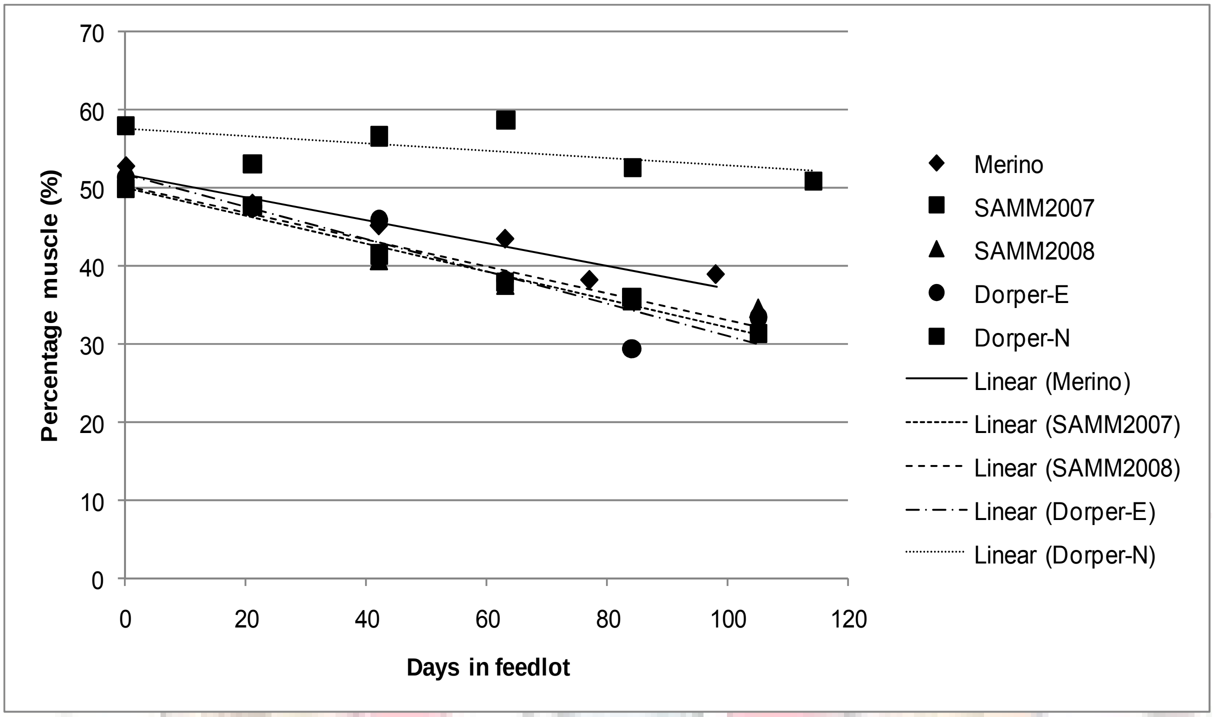

Figure 1 Regression lines between days in feedlot and percentage muscle for Merino, SAMM and Dorper lambs with an increase in the number of days under feedlot conditions.

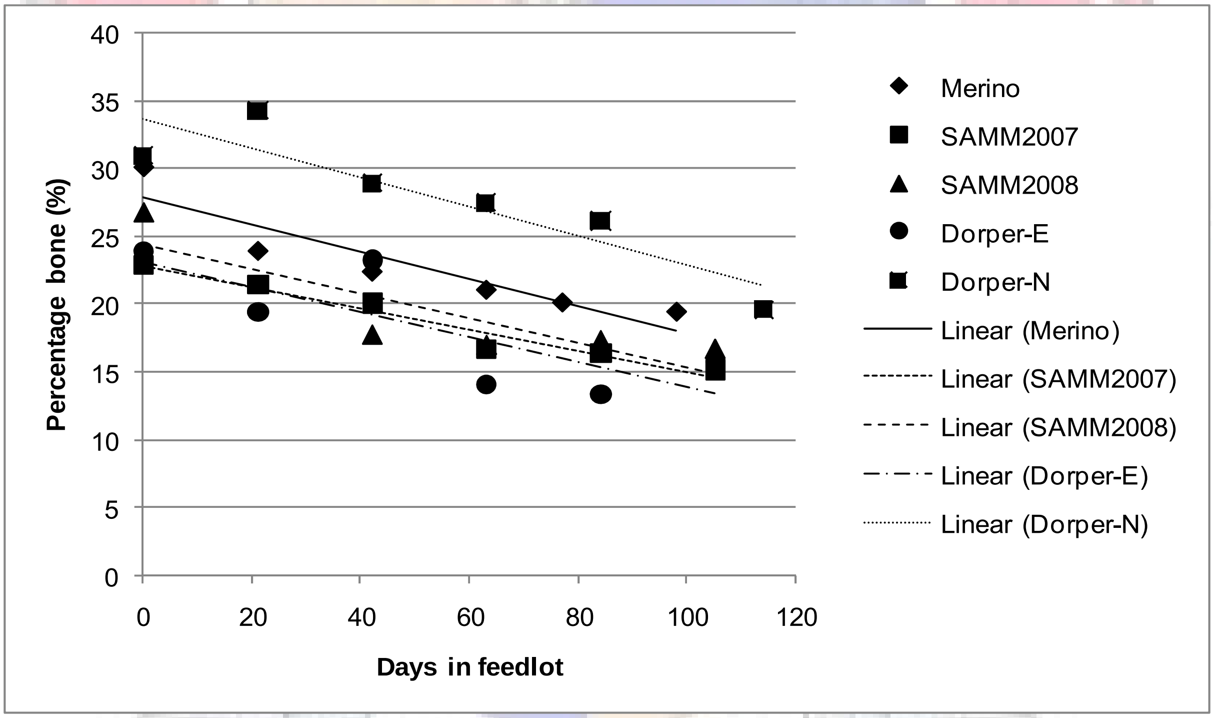

Figure 2 Regression lines between days in feedlot and percentage bone for Merino, SAMM and Dorper lambs with an increase in the number of days under feedlot conditions.

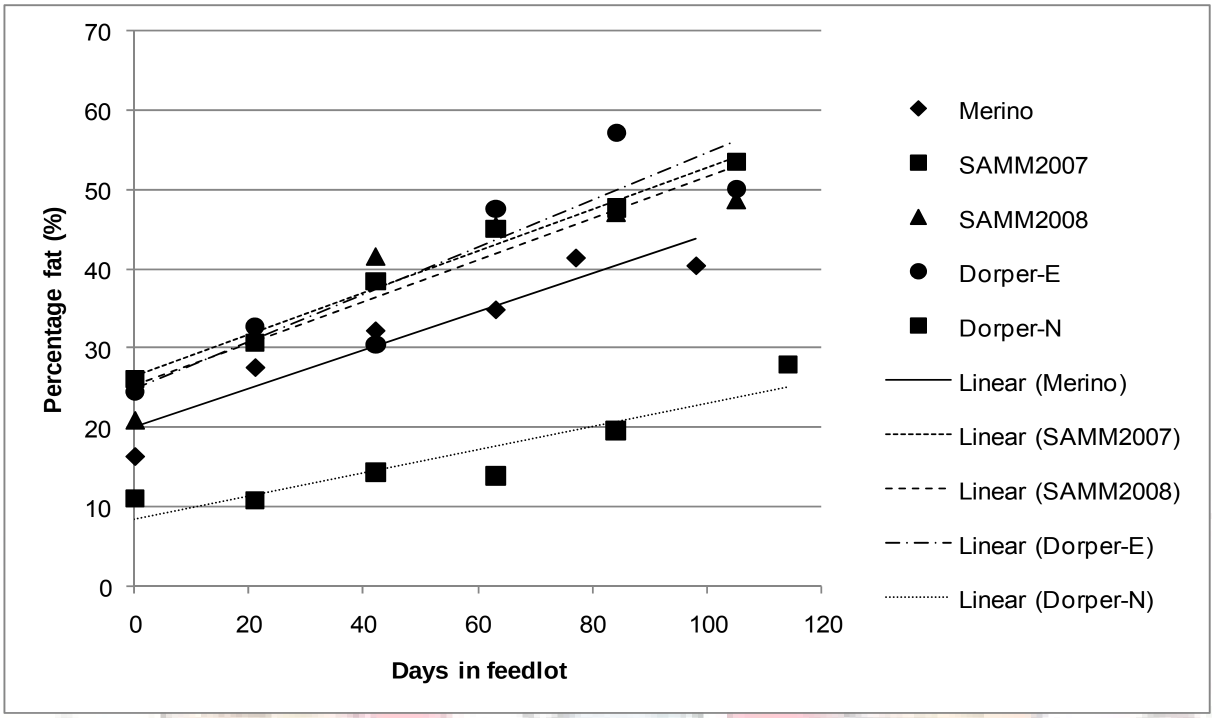

Figure 3 Regression lines between days in feedlot and percentage fat for Merino, SAMM and Dorper lambs with an increase in the number of days under feedlot conditions.

Table 12 Linear equations for the change in percentage of muscle, bone and fat for Merino, SAMM and Dorper lambs with an increase in the number of days under feedlot conditions.

Production group	Muscle	R^2	Bone	R^2	Fat	R^2
Merino	y=-0.1465x + 51.836	0.934	y=-0.0993x + 27.830	0.841	y=0.2424x + 20.028	0.902
SAMM 2007	y=-0.1792x + 50.135	0.980	y=-0.0784x + 22.869	0.957	y=0.2630x + 26.419	0.986
SAMM 2008	y=-0.1716x + 50.201	0.907	y=-0.0902x + 24.421	0.727	y=0.2618x + 25.376	0.852
Dorper-E	y=-0.2069x + 51.802	0.882	y=-0.0913x + 23.080	0.621	y=0.2977x + 24.781	0.815
Dorper-N	y=-0.0457x + 57.516	0.361	y=-0.1076x + 33.722	0.826	y=0.1455x + 8.458	0.858

Results from Table 12 indicate that the percentage lean and bone will decrease with an increase in time spent under feedlot conditions, while the percentage fat will increase. Age has an effect ($P<0.05$) on the amount of muscle, bone and fat in a carcass for Merino, SAMM and Dorper lambs. These findings are similar to those of Goliomytis *et al*. (2006), who showed that an increase in lamb age resulted in an increase in the amount of fat, and a decrease in the amount of muscle and bone in a carcass. They also found that ewe lambs produced fatter carcasses than their male counterparts. As castrates were used in this investigation, this phenomenon could not be tested. The castrates did not differ from the ewes as pertaining to the level of fatness in this investigation.

The 2007 SAMM group had the highest percentage fat (53.4 ± 1.41), but the lowest percentage bone (15.1 ± 0.76) of all the groups at the end of the production period. The Merino lambs started with a high percentage muscle (52.8 ± 1.38) and very low percentage fat (16.4 ± 1.77). This difference became smaller, and almost constant towards the end of the production period (muscle = 39.0 ± 1.22 %, and fat = 40.5 ± 1.57 %). In both SAMM groups, the difference between the amount of muscle and bone was the least after 42 days in the feedlot.

The Elsenburg Dorper group started with 51.3 ± 2.23 % muscle and ended with 33.4 ± 2.03 % while the % fat started at 24.5 ± 2.72 and ended with 50.2 ± 2.48 % after the 105 day production period. The Nortier Dorpers achieved the highest % muscle (51.0 ± 1.73) after their 114-day production period; this was accompanied by the lowest % fat (28.0 ± 1.84). The reason why the animals from this specific group had superior muscle: bone: fat ratio when compared to the other groups could not be explained.

4.4. Conclusion

In this investigation the lambs received a high energy diet and had little available space for exercise. Both these factors contributed to the increase in both renal and visceral fat deposition in all the breeds. The early maturing Dorpers gained fat readily throughout the production period, while the SAMM gain fat at a slower rate than the Dorpers and the leaner Merino lambs did not reach the high fat levels attained by the Dorper and SAMM breeds. The early maturing Dorper lambs produced the heaviest and fattest carcasses of all the breeds, followed by the SAMM and then the leaner Merino breed.

The percentage muscle and bone decreased throughout the production period and an increase in the percentage fat was documented with an increase in the number of days under feedlot conditions. As the production period commenced, the carcasses attained less muscle and more fat, while the percentage bone also decreased for all the breeds throughout the production period. All production groups achieved the highest percentage muscle when slaughtered prior to being housed in the feedlot, and the highest percentage fat was achieved in either the last or second last slaughter dates.

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Chapter 5

The effect of feedlot production on the meat quality characteristics of Merino, South African Mutton Merino and Dorper lambs

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Abstract

The objective of this study was to determine the effect of the number of days fed under various feedlot conditions on the physical meat quality characteristics of Merino, South African Mutton Merino (SAMM) and Dorper lambs. Lambs received a balanced diet (16% protein, 10 MJ ME/kg feed) and had free access to water. The lambs from each breed were divided into six groups. A group of each breed was slaughtered every three weeks until a production period of approximately 105 days under feedlot conditions was reached. An increase in carcass fatness decreased the cooling rate for all production groups and resulted in a lower rate of pH decline *post* mortem. Meat of Merino, SAMM 2007 and both Dorper production groups indicated that a low pH 48h *post mortem* is accompanied by higher percentages cooking and drip loss as well as a high a*-colour reading. Lambs from the 2008 SAMM group were the oldest when weaned and achieved the highest shear force values of all the production groups. The group of lambs (from all production groups) that were not housed in the feedlot (slaughtered at day 0), had the highest shear force values This effect can be explained by the stress associated with the weaning of lambs and because these lambs were slaughtered from a free-range system.

5.1. Introduction

When consumers purchase red meat, the colour of the meat is the most important attribute associated with freshness (Kerry *et al*., 2000). This is, however, only true when meat odour is not detected first. The amount of visible fat will not only make the meat appear lighter but it is also associated with health aspects and will also influence the purchasing behaviour of consumers (Grunert, 2006). The re-purchasing of meat is primarily affected by the tenderness of the meat upon consumption (Koohmaraie *et al*., 1990, Safari *et al*., 2001).

The oxygenation of myoglobin, when meat is exposed to air, is responsible for the bright red colour of lamb (Lawrie, 1998). The concentration of haeme proteins such as haemoglobin, myoglobin and cytochrome C, their chemical state, the type of myoglobin present and the light scattering properties of meat are all factors influencing meat colour (Lawrie, 1998). Lambs fed a concentrate ration tend to have meat that is lighter in colour when compared to meat produced by extensive production systems (Priolo *et al*., 2002). This phenomenon can partially be explained by the rate of pH decline, with grass fed lambs having a higher rate of pH decline and a higher ultimate pH (pHu) (Priolo *et al*., 2002). Colour is generally not influenced by gender in younger animals (Jeremiah *et al*. 1991; Vergara *et al*., 1999), although differences between genders have been reported (Johnson *et al*., 2005).

Dransfield *et al*. (1990), reported that gender had no influence on pHu, but a low pHu is associated with more tender and palatable meat (Gardener *et al*., 1999). Meat tenderness is also influenced by carcass fatness (Priolo *et al*., 2002). It is generally accepted that intact males produce leaner carcasses than both ewe and castrates, but the meat produced by both ewe and castrate lambs are more tender (Field, 1971; Seideman *et al*., 1982).

This study investigated the effect of feedlot production on the physical meat quality characteristics of Merino, South African Mutton Merino (SAMM) and Dorper lambs. The effect of gender on meat quality of feedlot-produced lambs was also investigated, however, as the feedlot conditions (year, age at entry into feedlot and production site) differed between the production groups, no comparisons between breeds were made.

5.2. Materials and methods

5.2.1. Lamb management

Merino, South African Mutton Merino (SAMM) and Dorper lambs were finished off under feedlot conditions and slaughtered at different ages. Five production groups were used for the experiment. The Merino, two SAMM groups and a group of Dorper sheep were housed in a feedlot on the Elsenburg Experimental farm, while another group of Dorper lambs were housed in a feedlot on the Nortier Experimental farm near Lamberts Bay. Only castrate lambs were used for the Merino data while data from both castrate and ewe lambs were used for the other production groups. All lambs were vaccinated against pulpy kidney (*Clostridia perfringes D*) and dosed against internal parasites before entering the feedlot. In 2007, 113 Merino lambs were used and data from 126 SAMM lambs were collected, while 29 and 62 Dorper lambs were finished under feedlot conditions at Elsenburg and Nortier, respectively. In 2008, data from 104 SAMM lambs were collected.

Lambs were allocated randomly to pens in the feedlot and were not subjected to an adaptation period. The lambs were fed a commercial available balanced diet (16% protein, 10MJ ME/kg feed) (see Chapter 2 for full formulation) *ad libitum* and had free access to water. All lambs were divided into six slaughter groups. The control group was not housed in the feedlot and was slaughtered at weaning. Thereafter, a group of lambs were slaughtered every 21 days. The last group was slaughtered after a 105-day production period in the feedlot. The amount of days in the feedlot differed for both the Merino and Dorper (produced at Nortier) lambs, due to practical arrangements during the festive season regarding the slaughter of the lambs.

5.2.2. Slaughter procedures

Merino, SAMM and Dorper lambs fed at Elsenburg, were slaughtered at a commercial abattoir (Roelcor) in Malmesbury and the Dorpers produced at Nortier were slaughtered at Vredendal abattoir – also a commercial abattoir. Each slaughter group was weighed 24h prior to slaughter; this weight was used as the final slaughter weight. After being weighed lambs were loaded and transported to the abattoir with minimum stress. The transport duration was approximately 45 minutes from Elsenburg to Malmesbury, as well as from Nortier to Vredendal. Lambs were kept in lairage at the abattoirs for 18h prior to slaughter to allow sufficient resting time and water was provided *ad libitum*. Lambs were rendered unconscious by electrical stunning (200V for 4 seconds) and slaughtered using standard South African techniques. Carcass dressing and classification was completed 20 minutes *post mortem* and the carcasses were hung in random order in the cooler 1h *post mortem*. No electrical stimulation was applied. The following day carcasses was transported to a deboning facility and kept in a cooler for another 24h prior to sampling.

5.2.3. Data collection

The *longissimus dorsi* (LD) muscle was used for instrumental analyses of the meat. Muscle pH and temperature measurements were made on the right side of each carcass by inserting a portable pH meter equipped with pH and temperature probe into the LD muscle between the 1st and 6th lumber vertebra. None of the subsequent pH and temperature measurements were taken at the exact same place. The first pH and temperature readings were taken 45 minutes *post mortem* and were denoted pH45 and Temp45 in the results. The second reading was taken 48h *post mortem* and was denoted pH48 and Temp48, respectively. The pH meter was calibrated with standard buffers at pH 4.0 and pH 7.0 prior to sampling. After pH and temperature readings were taken 48h *post mortem*, the LD muscle from the left side of each carcass was excised for meat quality analysis (Schönfeldt *et al*., 1993).

All visible fat, including subcutaneous fat, was removed prior to meat quality analysis being done. Two loin sub-samples of 1.0 to 1.5 cm thick were taken, the first at the first lumbar vertebra and the second, directly adjacent to the first. These two samples were used to determine cooking loss, drip loss, colour measurements and tenderness of the meat. Samples were allowed to bloom for 30 minutes at room temperature (18 - 19°C) before colour readings were recorded according to the method described by Honikel (1998). Colour measurements were taken in triplicate for each sample at randomly selected positions. A Color-guide 45°/0° (BYK-Gardner, USA) was used to determine L*, a* and b* coordinates of the CIELab colorimetric space (Minolta, 1998). The L* coordinate indicates the lightness of the meat, a* the red-green range and b* the blue-yellow range. The Hue angle (h^{ab}) and Chroma values of the meat was calculated by subjecting the a* and b* coordinates to the following equations (Commission International de l'Eclairage, 1976): Hue angle (h^{ab}) = $\tan^{-1}(b^*/a^*)$, Chroma (C*) = $\sqrt{(a^{*2} + b^{*2})}$.

One of the 1.0-1.5 cm thick meat samples was used to determine drip loss. The sample was weighed and then suspended in a plastic bag filled with air for 24h in a cooler at 4°C. After 24h the sample was removed, blotted dry with a tissue paper and weighed. Drip loss was then expressed as a percentage of the difference between the initial and final weight over the initial weight. Cooking loss was determined by weighing a 1.0-1.5 cm thick sample and placing the raw meat in a plastic bag in a pre-heated water bath (80°C) for 1h (Cloete *et al*., 2005). The cooked meat sample was removed after 1h in the water bath and placed in a cooler for 24h at 4°C. Samples were blotted with tissue paper to remove the excess water before the final weight was recorded. The weight loss of each sample was expressed as a percentage of the initial weight of the raw sample. The method used to determine meat tenderness was described by Honikel (1998). A Warner Bratzler device, with a load cell of 2.000 kN attached to a model 4444 Instron texture machine (Apollo Scientific cc, South Africa) was used to asses meat tenderness. This machine has a measuring speed of 200.0 mm/min. Meat samples were small and only three cores per sample could be used. Cores (1.27 cm in diameter) were removed from each cooked sample parallel to the muscle fibre axis to ensure the blade of the Warner Bratzler device cuts across the fibres at right angles. Values used for statistical analysis of meat tenderness are the mean values attained from the three samples.

5.2.4. Statistical analysis

Differences in physical meat quality characteristics between slaughter groups and the effect of gender on these variables were established by subjecting the data to Proc GLM (SAS, 2006). The full model, i.e. the effect of the number of days housed in the feedlot and gender and the interaction among the main effects was used for the preliminary analysis. Gender was not included as a main effect for Merino lambs because only castrate lambs were used. As there were no interaction between the two main effects and gender did not differ at any fixed period (days in feedlot), the final analysis only evaluated days housed under feedlot conditions as the main effect. Data from both genders were therefore pooled in the results. The values given in the following tables are least square means followed by their accompanying standard error (s.e.).

5.3. Results and discussion

As there was no interaction between the number of days housed under feedlot conditions and gender (P<0.05), least square means depicting the main effects of the parameters measured was tabulated. All tables contain the least square mean of each parameter measured with its accompanying standard error (±

s.e.). Results in Tables 1 to 5 show the effect of the number of days housed under feedlot conditions on the physical meat quality characteristics of Merino, SAMM and Dorper lambs.

In Table 1, no significant difference was found for pH48 between 21 and 77 days under feedlot conditions. Similarly, no difference was found in this period for cooking loss, drip loss, a* or b* colour readings for Merino lambs. The lowest pH48 reading was for the initial group of lambs slaughtered that were not housed in the feedlot, these lambs also attained the highest percentage cooking and drip loss. According to Swatland (1995), the water holding capacity (WHC) of meat is influenced by the muscle pH and the rate of pH decline *post mortem*, and results obtained by Onyango *et al.* (1998) showed an elevated pHu to be accompanied by a decrease in moisture losses, therefore increasing the WHC. These effects on pHu on cooking and drip loss percentage, and the effect of pHu on the a* colour reading was found for SAMM 2007 (Table 2), the Elsenburg Dorper group (Table 4) and the Nortier Dorper group (Table 5).

The temperature readings taken 48h *post mortem* showed a tendency to increase with an increase in the number of days spent under feedlot conditions. Results from Chapter 4, showed that carcasses increased in fatness with an increase in the number of days under feedlot conditions. According to Lawrie (1998) and French *et al*. (2001), fatter carcasses will cool down at a slower rate than lean carcasses. This effect will result in a higher rate of *post mortem* glycolysis for fatter carcasses, meaning fatter carcasses will attain their lower pHu earlier and normally at a higher temperature.

Results for the SAMM 2008 group (Table 3), showed the lowest percentage drip loss and highest percentage cooking loss for the lambs that were slaughtered at the beginning of the trial. These values were further accompanied by the highest shear force values (78.08 ± 2.74) in all production groups. Several factors may have caused this effect; firstly being the nutritional status of the animal at slaughter. This specific group of lambs (SAMM 2008) was weaned at an average age of 140.0 ± 0.85 days, while the SAMM 2007, Elsenburg Dorper and Nortier Dorpers were weaned at an average age of 122.3 ± 0.65, 127.7 ± 2.15 and 86.5 ± 0.72 days, respectively. The reason for the older weaning age of the 2008 SAMM lambs is because they did not grow as efficiently on the pasture pre-weaning as the other production groups. The 2007 SAMM group had an average live weight of 35.5 ± 0.46 kg when they were weaned, while the 2008 group only weighed 30.0 ± 0.43 kg at weaning. Another reason for the lowest percentage drip loss and highest percentage cooking loss can be ascribed to the effect of stress. Along with the stress on the bodies of these lambs due to the low quality pasture, these lambs were loaded on the farm and transported directly to the abattoir. Results from this study are in accordance with those of Devine *et al*. (1993), who found that stress and nutritional status before slaughter are two major determinants for pHu. Meat tenderness is dependent on rate of pH decrease as well as pHu (Kristensen *et al*., 2006) and can be influenced by an animal’s growth pattern (Harper, 1999), explaining why such a high shear force value was found for these lambs.

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Table 1 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the physical meat quality characteristics of Merino lambs.

	Parameter Measured											
	pH45	Temp45 (ºC)	pH48	Temp48 (ºC)	Cooking loss (%)	Drip loss (%)	Colour L*	a*	b*	Hue angle	Chroma	Tenderness (N)
n	113	113	108	108	107	103	108	108	108	108	108	108
Days housed in feedlot												
0	6.5^{bc} ± 0.08	24.8^{d} ± 0.45	5.3^{c} ± 0.05	2.8^{c} ± 0.08	26.4^{a} ± 1.01	2.2^{a} ± 0.18	36.3^{c} ± 0.50	10.9^{c} ± 0.31	7.9^{b} ± 0.43	35.6^{a} ± 1.36	13.5^{c} ± 0.34	42.6^{b} ± 2.16
21	6.7^{ab} ± 0.08	28.2^{c} ± 0.47	5.6^{ab} ± 0.05	2.1^{d} ± 0.07	23.5^{ab} ± 0.89	1.3^{b} ± 0.14	35.1^{c} ± 0.46	14.7^{a} ± 0.28	8.9^{ab} ± 0.39	31.1^{ab} ± 1.24	17.2^{ab} ± 0.31	58.1^{a} ± 1.98
42	6.9^{a} ± 0.08	35.4^{a} ± 0.46	5.4^{bc} ± 0.05	7.5^{a} ± 0.07	22.0^{b} ± 0.87	1.2^{b} ± 0.13	42.7^{a} ± 0.44	15.3^{a} ± 0.27	8.9^{ab} ± 0.38	30.0^{b} ± 1.21	17.9^{a} ± 0.30	27.4^{c} ± 1.92
63	6.4^{bc} ± 0.08	32.3^{b} ± 0.47	5.6^{ab} ± 0.05	1.8^{e} ± 0.07	21.0^{b} ± 0.89	1.1^{b} ± 0.14	39.8^{b} ± 0.46	14.7^{a} ± 0.28	8.5^{ab} ± 0.39	30.0^{b} ± 1.24	17.0^{ab} ± 0.31	57.5^{a} ± 1.98
77	6.4^{bc} ± 0.08	32.9^{b} ± 0.46	5.6^{ab} ± 0.05	3.5^{b} ± 0.07	20.9^{b} ± 0.87	1.0^{b} ± 0.13	38.6^{b} ± 0.44	14.5^{a} ± 0.27	7.9^{b} ± 0.38	28.5^{b} ± 1.21	16.5^{b} ± 0.30	42.1^{b} ± 1.92
98	6.3^{c} ± 0.08	36.5^{a} ± 0.46	5.7^{a} ± 0.05	2.7^{c} ± 0.07	23.3^{ab} ± 0.87	0.7^{b} ± 0.13	36.0^{c} ± 0.44	13.2^{b} ± 0.27	9.6^{a} ± 0.38	35.9^{a} ± 1.21	16.4^{b} ± 0.30	37.0^{b} ± 1.92
P-Value												
Days in feedlot	<0.0001	<0.0001	<0.0001	<0.0001	0.0006	<0.0001	<0.0001	<0.0001	0.0154	<0.0001	<0.0001	<0.0001

$^{a\text{-}e}$ means in a column with different superscript letters differ ($P<0.05$).

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Table 2 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the physical meat quality characteristics of SAMM lambs produced in 2007.

	Parameter Measured											
	pH45	Temp45 (ºC)	pH48	Temp48 (ºC)	Cooking loss (%)	Drip loss (%)	Colour			Hue angle	Chroma	Tenderness (N)
							L*	a*	b*			
n	126	126	124	124	126	121	126	126	126	126	126	126
Days housed in feedlot												
0	6.6^{ab} ± 0.09	30.6^{b} ± 0.57	5.6^{b} ± 0.05	1.5^{e} ± 0.09	17.8^{ab} ± 0.62	2.1^{a} ± 0.09	39.0^{ab} ± 0.50	12.0^{c} ± 0.31	11.1^{a} ± 0.31	43.0^{a} ± 0.91	16.4^{bc} ± 0.35	27.6^{a} ± 1.09
21	6.8^{a} ± 0.09	30.6^{b} ± 0.57	5.7^{ab} ± 0.05	9.0^{a} ± 0.09	19.6^{a} ± 0.62	1.0^{c} ± 0.09	37.8^{bc} ± 0.50	12.0^{c} ± 0.30	8.8^{c} ± 0.31	36.2^{bc} ± 0.91	15.0^{c} ± 0.35	18.1^{c} ± 1.09
42	6.6^{ab} ± 0.09	32.7^{b} ± 0.57	5.9^{a} ± 0.05	2.9^{d} ± 0.09	19.9^{a} ± 0.62	1.1^{c} ± 0.09	37.3^{bc} ± 0.50	13.0^{bc} ± 0.31	10.9^{ab} ± 0.31	40.1^{a} ± 0.91	17.0^{ab} ± 0.35	27.7^{a} ± 1.09
63	6.5^{ab} ± 0.09	32.6^{b} ± 0.56	5.6^{bc} ± 0.05	3.0^{d} ± 0.09	16.2^{b} ± 0.61	1.8^{ab} ± 0.10	38.2^{bc} ± 0.50	13.4^{b} ± 0.30	11.3^{a} ± 0.31	40.1^{ab} ± 0.90	17.5^{ab} ± 0.34	25.2^{ab} ± 1.08
84	6.3^{b} ± 0.09	35.2^{a} ± 0.57	5.4^{cd} ± 0.05	3.5^{c} ± 0.09	18.2^{ab} ± 0.62	1.5^{b} ± 0.09	36.6^{c} ± 0.50	13.8^{b} ± 0.30	11.9^{a} ± 0.31	40.7^{a} ± 0.91	18.2^{a} ± 0.35	27.3^{ab} ± 1.09
105	6.3^{b} ± 0.10	36.0^{a} ± 0.58	5.3^{d} ± 0.05	3.9^{b} ± 0.09	13.4^{c} ± 0.63	0.8^{c} ± 0.09	40.4^{a} ± 0.51	15.4^{a} ± 0.31	9.8^{bc} ± 0.32	32.3^{c} ± 0.93	18.2^{a} ± 0.35	27.8^{a} ± 1.11
P-Value												
Days in feedlot	0.0122	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

$^{a-e}$ means in a column with different superscript letters differ (P<0.05).

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Table 3 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the physical meat quality characteristics of SAMM lambs produced in 2008.

	Parameter Measured											
	pH45	Temp45 (ºC)	pH48	Temp48 (ºC)	Cooking loss (%)	Drip loss (%)	Colour			Hue angle	Chroma	Tenderness (N)
							L*	a*	b*			
n	87	87	104	104	87	87	87	87	87	87	87	87
Days housed in feedlot												
0	6.5^{b} ± 0.05	29.0^{c} ± 0.51	5.5^{b} ± 0.03	2.5^{b} ± 0.12	29.7^{a} ± 0.63	0.6^{c} ± 0.06	40.4^{a} ± 0.55	11.4^{b} ± 0.30	9.9^{b} ± 0.29	40.9 ± 0.73	15.1^{b} ± 0.34	78.1^{a} ± 2.74
42	6.2^{c} ± 0.06	31.5^{b} ± 0.62	5.5^{b} ± 0.03	1.5^{c} ± 0.15	26.8^{ab} ± 0.77	1.1^{ab} ± 0.07	36.4^{b} ± 0.66	14.9^{a} ± 0.36	11.8^{a} ± 0.35	38.5 ± 0.89	19.0^{a} ± 0.42	62.0^{bc} ± 3.33
63	6.8^{a} ± 0.06	36.1^{a} ± 0.61	5.7^{a} ± 0.03	3.4^{a} ± 0.14	25.1^{bc} ± 0.75	1.1^{b} ± 0.07	37.3^{b} ± 0.65	14.5^{a} ± 0.35	12.5^{a} ± 0.34	40.7 ± 0.87	19.2^{a} ± 0.41	60.3^{bc} ± 3.24
84	6.3^{bc} ± 0.06	36.8^{a} ± 0.63	5.5^{b} ± 0.03	3.6^{a} ± 0.15	21.8^{d} ± 0.78	1.2^{ab} ± 0.07	37.2^{b} ± 0.67	14.2^{a} ± 0.36	12.2^{a} ± 0.35	40.6 ± 0.90	18.7^{a} ± 0.42	55.8^{c} ± 3.37
105	6.4^{b} ± 0.06	31.8^{b} ± 0.65	5.5^{b} ± 0.03	2.1^{bc} ± 0.15	22.9^{cd} ± 0.80	1.3^{a} ± 0.07	37.8^{b} ± 0.69	14.0^{a} ± 0.38	11.2^{ab} ± 0.36	38.5 ± 0.93	18.0^{a} ± 0.43	69.2^{ab} ± 3.46
P-Value												
Days in feedlot	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.11	<0.0001	<0.0001

$^{a\text{-}d}$ means in a column with different superscript letters differ ($P<0.05$).

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Table 4 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the physical meat quality characteristics of Dorper lambs produced at Elsenburg Experimental farm.

	Parameter Measured											
	pH45	Temp45 (ºC)	pH48	Temp48 (ºC)	Cooking loss (%)	Drip loss (%)	Colour			Hue angle	Chroma	Tenderness (N)
							L*	a*	b*			
n	29	29	26	26	29	29	29	29	29	29	29	29
Days housed in feedlot												
0	$6.8^{ab} \pm 0.11$	$31.8^{bc} \pm 1.08$	$5.4^{b} \pm 0.10$	$1.3^{c} \pm 0.21$	$22.1^{a} \pm 1.46$	$2.3^{a} \pm 0.26$	$37.7^{a} \pm 1.09$	$12.4^{bc} \pm 0.77$	10.7 ± 0.72	40.9 ± 2.72	$16.4^{ab} \pm 0.74$	$29.1^{ab} \pm 3.34$
21	$7.0^{a} \pm 0.10$	$29.5^{c} \pm 0.99$	$5.8^{a} \pm 0.09$	$9.2^{a} \pm 0.18$	$20.7^{a} \pm 1.33$	$1.1^{bc} \pm 0.24$	$37.2^{a} \pm 0.99$	$11.7^{c} \pm 0.70$	8.7 ± 0.65	36.7 ± 2.48	$14.6^{b} \pm 0.68$	$21.4^{c} \pm 3.04$
42	$6.4^{bc} \pm 0.10$	$33.0^{bc} \pm 0.99$	$5.8^{a} \pm 0.09$	$2.7^{b} \pm 0.18$	$20.9^{a} \pm 1.33$	$1.1^{bc} \pm 0.24$	$33.2^{bc} \pm 0.99$	$12.5^{bc} \pm 0.70$	9.1 ± 0.65	36.3 ± 2.48	$15.7^{b} \pm 0.68$	$24.1^{bc} \pm 3.04$
63	$6.6^{b} \pm 0.11$	$33.5^{ab} \pm 1.10$	$5.7^{ab} \pm 0.21$	$3.1^{b} \pm 0.42$	$16.0^{ab} \pm 1.48$	$2.3^{a} \pm 0.26$	$34.6^{bc} \pm 1.10$	$13.8^{b} \pm 0.78$	10.3 ± 0.73	36.7 ± 2.76	$17.2^{ab} \pm 0.75$	$24.8^{bc} \pm 3.38$
84	$6.6^{b} \pm 0.10$	$34.5^{ab} \pm 0.99$	$5.9^{a} \pm 0.09$	$3.6^{b} \pm 0.18$	$13.4^{b} \pm 1.33$	$1.3^{bc} \pm 0.24$	$33.2^{c} \pm 0.99$	$15.4^{a} \pm 0.70$	11.2 ± 0.65	36.0 ± 2.48	$19.0^{a} \pm 0.68$	$25.7^{bc} \pm 3.04$
105	$6.1^{c} \pm 0.10$	$37.0^{a} \pm 0.99$	$5.4^{b} \pm 0.09$	$3.8^{b} \pm 0.18$	$12.4^{b} \pm 1.33$	$0.7^{c} \pm 0.24$	$37.9^{ab} \pm 0.99$	$16.2^{a} \pm 0.70$	10.6 ± 0.65	32.9 ± 2.48	$19.4^{a} \pm 0.68$	$34.3^{a} \pm 3.04$
P-Value												
Days in feedlot	<0.0001	0.0007	0.0029	<0.0001	<0.0001	0.0007	0.0032	0.0007	0.0794	0.4937	0.0002	0.0817

$^{a-c}$ means in a column with different superscript letters differ (P<0.05).

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Table 5 Least square means (± s.e.) depicting the effect of number of days under feedlot conditions on the physical meat quality characteristics of Dorper lambs produced at Nortier Experimental farm.

	Parameter Measured											
	pH45	Temp45 (ºC)	pH48	Temp48 (ºC)	Cooking loss (%)	Drip loss (%)	Colour			Hue angle	Chroma	Tenderness (N)
							L*	a*	b*			
n	62	62	40	40	62	62	62	62	62	62	62	62
Days housed in feedlot												
0	6.3^{ab} ± 0.15	38.1^{a} ± 0.61	5.4^{b} ± 0.03	4.8^{c} ± 0.28	27.7^{a} ± 0.91	1.5^{cd} ± 0.17	38.3^{b} ± 0.64	12.4^{bc} ± 0.43	8.8^{bc} ± 0.47	35.2^{a} ± 1.43	15.3^{b} ± 0.48	32.0^{ab} ± 2.13
21	6.0^{b} ± 0.15	34.7^{c} ± 0.61	5.4^{b} ± 0.03	7.5^{a} ± 0.28	28.3^{a} ± 0.91	1.3^{cd} ± 0.17	35.6^{c} ± 0.64	12.7^{bc} ± 0.43	8.6^{c} ± 0.47	34.1^{ab} ± 1.43	15.4^{b} ± 0.48	24.9^{bc} ± 2.13
42	6.4^{ab} ± 0.15	35.6^{bc} ± 0.59	5.7^{a} ± 0.03	5.7^{bc} ± 0.27	22.4^{b} ± 0.88	3.0^{a} ± 0.18	38.0^{bc} ± 0.62	11.8^{c} ± 0.41	8.6^{c} ± 0.45	36.1^{a} ± 1.38	14.7^{b} ± 0.47	25.9^{bc} ± 2.06
63	6.0^{b} ± 0.15	38.0^{ab} ± 0.59	-	-	22.9^{b} ± 0.90	2.3^{b} ± 0.16	36.4^{bc} ± 0.62	14.0^{b} ± 0.42	11.4^{a} ± 0.46	39.1^{a} ± 1.40	18.1^{a} ± 0.47	19.5^{c} ± 2.09
84	6.0^{b} ± 0.15	34.0^{c} ± 0.61	5.2^{c} ± 0.03	6.7^{ab} ± 0.28	20.1^{b} ± 0.91	0.8^{d} ± 0.17	42.0^{a} ± 0.64	16.0^{a} ± 0.43	10.7^{ab} ± 0.47	33.8^{ab} ± 1.43	19.3^{a} ± 0.48	21.2^{c} ± 2.13
114	6.8^{a} ± 0.14	28.0^{d} ± 0.55	-	-	27.3^{a} ± 0.83	1.9^{bc} ± 0.15	38.8^{b} ± 0.58	15.8^{a} ± 0.39	8.7^{c} ± 0.42	29.0^{b} ± 1.29	18.1^{a} ± 0.44	38.2^{a} ± 1.93
P-Value												
Days in feedlot	0.0009	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

$^{a-d}$ means in a column with different superscript letters differ ($P<0.05$).

Warner Bratzler shear force values for SAMM (Tables 2 and 3) and Dorper (Tables 4 and 5) lambs in both production groups showed similar results. Shear force values for these groups did not differ (P<0.05) from each other at weaning, after 42 days and 105 days (114 days for the Nortier Dorpers) under feedlot conditions. The lowest shear force values for these groups were found after 21 days in the feedlot. Merino lambs (Table 1) achieved their lowest shear force value after 42 days under feedlot conditions.

Santos-Silva *et al*. (2002) and Teixeira *et al*. (2005) concluded that an increase in live weight (number of days under feedlot conditions) is associated with a decrease in lightness (L*) and yellowness (b*), similar results were however not found in this study. Lightness values for all production groups decreased significantly between the groups slaughtered directly after weaning and those housed in the feedlot for 21 days. According to Martinez-Cerezo *et al*. (2005), a greater effect in meat colour is brought about by a change in diet, than either carcass weight or age. It is worth noting that the lowest pH45 reading was achieved by the Elsenburg Dorper lambs (Table 4) after 84 days in the feedlot (5.99 ± 0.15). This low pH value was accompanied by a high L* value.

5.4. Conclusion

An increase in the number of days spent under feedlot conditions led to an increase in carcass fatness (Chapter 4), this in turn decreased the rate of *post mortem* cooling which resulted in a higher rate of pH decline for all the production groups. A low pH48 reading was accompanied by a high percentage cooking and drip loss and a high a*-colour value for Merino, SAMM 2007 and both Dorper production groups. The 2008 SAMM lambs were weaned at an older age than their 2007 counter parts and had less tender meat. Colour readings obtained in this study showed no conclusive results.

The high shear force values obtained in the groups of lambs that were slaughtered without being housed in the feedlot can be best explained by their physiological responses to stress. Another explanation can be that these lambs were slaughtered directly from a free-range system, and had minimal contact with humans and would have therefore been stressed. The feedlot animals on the other hand were exposed on a daily basis to a lot of human interaction resulting in them becoming habituated to humans. When they were then consequently slaughtered they would not have been stressed to the same extent. By subjecting the lambs to an adaptation period before weaning could eliminate these effects. Meat tenderness is the main criterion affecting the repurchasing of meat. The lowest shear force value for Merino lambs was measured after 42 days in the feedlot, for the 2007 SAMM group and Elsenburg Dorper group after 21 days, for the 2008 SAMM group after 84 days and the Nortier Dorpers after 63 days under feedlot conditions.

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Chapter 6

General conclusions and future perspectives

The current economic status of all countries makes it more profitable for farmers to finish off their lambs in a feedlot. This is due to the fact that as consumer demand for both mutton and lamb increases, an increase in the meat prices is also observed. It then becomes more profitable to finish off lambs in a feedlot, unless the feed price is too high (Brand *et al*., 2001). Also, environmental conditions and seasonal droughts make feedlotting of animals a viable option. This study was conducted to determine the effect of slaughter age or number of days in a feedlot on the lamb characteristics of Merino, South African Mutton Merino (SAMM) and Dorper lambs. Future research may be focused at the development of an economic model that takes the meat and feed prices into account and enables producers to slaughter their lambs at an optimal age/profit margin instead of an optimal weight. This model will enhance profits of producers because lambs with slow growth rates will not have to be fed more intensely to accumulate weight.

Tables 1 to 5 show the parameters measured in this study that has the most value to producers finishing their lambs under feedlot conditions. The number of days needed to achieve the most valuable economic result is marked with X. The A2 carcass rows indicate the number of days under feedlot conditions needed to obtain the highest percentage A2 graded carcasses within a specific slaughter group (producers receive the highest value for A2 graded carcasses). The retail yield is a combination of the hind-quarters, prime-rib and loin cuts (these cuts that have the highest economic value in a lamb carcass) and the percentage muscle was documented as the consumer demand for lean meat is an ever changing purchase criterion. Meat tenderness is the quality attribute mostly affecting the repurchasing of meat (Koohmaraie *et al*., 1990; Safari *et al*., 2001).

Table 1 Prediction of the optimal number of days in a feedlot for Merino lambs.

Parameter measured	Days in feedlot					
	0	21	42	63	77	98
Average daily gain (ADG)		X				
Feed conversion ratio (FCR)		X				
% A2 carcass			X			
Retail yield			X			
% Muscle	X					
Tenderness			X			

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Table 2 Prediction of the optimal number of days in a feedlot for SAMM lambs (data from 2007).

Parameter measured	Days in feedlot					
	0	21	42	63	84	105
Average daily gain (ADG)			X			
Feed conversion ratio (FCR)			X			
% A2 carcass		X				
Retail yield				X		
% Muscle	X					
Tenderness		X				

Table 3 Prediction of the optimal number of days in a feedlot for SAMM lambs (data from 2008).

Parameter measured	Days in feedlot					
	0	21	42	63	84	105
Average daily gain (ADG)		X				
Feed conversion ratio (FCR)		X				
% A2 carcass		X				
Retail yield					X	
% Muscle	X					
Tenderness					X	

Table 4 Prediction of the optimal number of days in a feedlot for Dorper lambs housed at Elsenburg Experimental farm.

Parameter measured	Days in feedlot					
	0	21	42	63	84	105
Average daily gain (ADG)			X			
Feed conversion ratio (FCR)		X				
% A2 carcass			X			
Retail yield				X		
% Muscle	X					
Tenderness		X				

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Table 5 Prediction of the optimal number of days in a feedlot of Dorper lambs housed at Nortier Experimental farm.

Parameter measured	Days in feedlot					
	0	21	42	63	84	114
Average daily gain (ADG)						X
% A2 carcass			X			
Retail yield				X		
% Muscle				X		
Tenderness				X		

Table 1 indicates that the optimal number of days to house Merino lambs in a feedlot is 42 days. Both ADG and FCR reached their peaks after only 21 days, but the most A2 carcasses and highest retail yield was achieved after 42 days under feedlot conditions. Producers receive the highest value for A2 graded carcasses (Van Heerden *et al*., 2007), despite the retail yield, percentage lean or the tenderness of the meat. The SAMM lambs produced in 2007 (Table 2) obtained their best values for growth ratio after 42 days in the feedlot, while the highest percentage A2 carcasses and most tender meat was reached in only 21 days. The 2008 SAMM lambs (Table 3), produced carcasses of the highest value also after only 21 days in the feedlot. The Elsenburg Dorper lambs (Table 4) indicated an optimum of between 21 and 42 days under feedlot conditions, while the Nortier Dorper group (Table 5) only reached their highest profit margin after 63 days under feedlot conditions.

Previous research has shown that the 3-rib cut is a very accurate method to predict carcass composition (Paulino *et al*., 2005). The 3-rib cut used for this study was made by dissecting the muscle, fat and bone between the 9th and 11th vertebra on the left side of the carcass. This meant that the carcass had to be split in the middle of the spinal column as best as possible. By not splitting the spinal column and dissecting the same area from both sides of the carcass, prediction of carcass composition can be made more accurately. Various online prediction methods are also available, these methods are more expensive, but they are more commonly used and no meat of the carcass is wasted.

Providing a creep feed to the lambs before entering the feedlot will ensure that the lambs grow more uniformly. Subjecting lambs to an adaptation period upon entering the feedlot can further enhance their growth performances and by implementing both adaptation strategies results will be enhanced further. Despite no adaptation period all three breeds performed well under the intensive feeding regimes.

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