A COMPARATIVE ANALYSIS OF NUTRIENT UTILISATION AND MEAT QUALITY PARAMETERS OF BOER GOATS AND SOUTH AFRICAN MUTTON MERINOS

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted it at any other university for a degree.

SUMMARY

A comparative analysis of nutrient utilisation and meat quality parameters of Boer goats and South African Mutton merinos

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One of the reasons why meat supply does not meet human demand is that man has concentrated on utilising relatively few animal species as a source of meat. Development of unconventional livestock, such as goats, is advocated as a means of increasing global meat production and consumption. Although South Africa possesses large numbers of domestic ruminants, meat consumption has been limited mainly to sheep and cattle. Goats are used to a lesser extent. This is partly attributed to a general belief that goat meat is inferior to mutton and beef.

Numerous contradictions regarding comparative goat and sheep growth, carcass characteristics and meat composition exist in literature. Concepts involved with most of the contradictions includes average daily gain (ADG), dressing percentage, carcass weight distribution and organoleptic characteristics, especially tenderness, juiciness and flavour, particularly as pertaining to animals reared/grown under intensive/feedlot conditions. Therefore this project was undertaken to obtain more information on the growth, carcass and organoleptic characteristics, as well as meat chemical compositions of Boer goat (BG) kids in comparison with South African Mutton merino (MM) lambs, reared under feedlot conditions.

Thirty-two BG kids and 32 MM lambs were used for this investigation. All the animals were castrated and weaned before entering the feedlot. Two pelleted diets (fed to 16 animals/species) with either a low (LE; 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) metabolisable energy level were fed individually, *ad lib* for either 28 or 56 days. Feed and water intake, ADG and feed conversion efficiencies (FCE) were monitored. During the last

week of the feeding trial, 12 BG kids and 12 MM lambs were used to evaluate the digestibility of the two diets.

After either 28 or 56 days, the animals were slaughtered and the carcasses dissected into South African commercial cuts. The *m. semimembranosus* and 8-9-10-rib cut of each carcass was dissected for determination of chemical composition, drip loss, cooking loss, shear force values and colour measurement. The *m. gracilis* was dissected from the hind leg of the carcass and used for sensory evaluation.

MM's had significantly higher ADG's than BG's (e.g. MMHE56: 0.281; BGHE56: 0.162 kg/day). Within a diet there was no difference ($P>0.05$) in FCE between BG's and MM's and only the MM's FCE differed between the LE and HE diet (e.g. BGLE28: 7.65; BGHE28: 6.37; MMLE28: 8.73; MMHE28: 5.56 kg feed/kg weight gain). BGLE digested dry matter (DM), crude protein (CP) and energy more efficiently and had a higher energy retention than MMLE. The two diets had the same ME-value for the goats, which confirms that goats perform equally well on a lower quality feed as their contemporaries on a higher quality feed. Neither species, nor diet affected nitrogen retention. The BG had a 49 % lower ($P<0.01$) water intake per kg weight gain than the MM on both the high and low energy diets. Both species had a lower ($P<0.01$) water intake on the high than on the low energy diet. Furthermore, the BG had a daily water intake of only 171 ml/kg$^{0.75}$ compared to the 302 ml/kg$^{0.75}$ of the MM.

The weight of the liver, empty stomach, head and feet (as a percentage of empty body weight) were higher in goats than in sheep. The MM's had significantly heavier skins, probably due to wool growth. Both kidney fat and gastro-intestinal tract (GIT) fat increased with age. The animals slaughtered after 56 days in the feedlot had significantly longer and deeper carcasses than their contemporaries slaughtered after 28 days. Within a diet and slaughter age, the MM had significantly broader and deeper carcasses than the BG's. BG's had significantly less weight per unit carcass length, and thus more slender carcasses than MM's. Diet had no significant influence on the carcass weight distribution of the goats. However, MM's had heavier carcasses (LE: 19.87 vs. 15.28 kg; HE: 24.01 vs. 17.05 kg) and proportionally heavier ribs and buttocks than BG's.

Neither diet nor slaughter age influenced the proximate analysis of the *m. semimembranosus*, but MM's had significantly lower moisture values than BG's. In the 8-9-10-rib cuts BG's had significantly more moisture and protein and lower fat and energy values than MM's. DM, fat and energy values increased with an increase in slaughter age in both species. BG's had significantly higher concentrations of 11 of the 18 measured essential amino acids in their 8-9-10-rib cuts than the MM's. Goat carcasses had higher Ca, K, Mg, Na and P-levels than sheep carcasses, regardless of the diet fed. There was a tendency for goat's *m. semimembranosus* to have a lower Fe-content than that of sheep.

BG carcasses had a lower carcass cholesterol content than that of lamb (66.77 vs. 99.28 mg/100g, respectively). Palmitic (C16:0), stearic (C18:0) and oleic (C18:1n9) acid comprised the greatest proportions of fatty acids in both the *m. semimembranosus* and 8-9-10-rib cut for both species. On a LE-diet there was no significant difference between the saturated fatty acid (SFA) to unsaturated fatty acid (UFA) ratio of goat meat and lamb. However, on the HE-diet, lamb had a significantly higher SFA:UFA ratio than chevon (*m. semimembranosus*: 0.842 vs. 0.689; 8-9-10-rib cut: 1.407 vs. 0.892). Organoleptically, a difference was noted between chevon and lamb. Each has a specific species flavour, which was not influenced by energy level of the diet. BG meat was perceived to be stringier than that of the MM, but there was no significant difference in Warner-Bratzler shear force values. Tenderness declined with age in both species and there was also a tendency for goat meat to be less juicy than lamb. Chevon had a more pronounced aftertaste than lamb. No objective differences could be distinguished between the colour of the cooked chevon and lamb. There was a tendency for fresh lamb to have a higher a*-value (redness) than chevon. Although diet did not influence drip loss, drip loss increased with an increase in slaughter age. Only after 56 days did the MM's *m. semimembranosus* have a significantly higher drip loss than the BG's (LE: 4.84 vs. 3.43%; HE: 4.72 vs. 3.32%). In the *m. semimembranosus* of both species, cooking loss increased with an increase in slaughter age.

Since diet did not influence the growth, carcass weight distribution, water holding capacity, colour, shear force values or organoleptic qualities of chevon, BG's may be finished on a diet with a lower ME-value than that usually formulated for sheep, without a reduction in performance. This may render a direct economic advantage for BG feedlot finishing. Meat from young feedlot goats is not inferior to that of lamb and it has a higher protein percentage and lower fat percentage. Therefore, it can be considered as a healthy food commodity, especially among low-income groups or people wishing to consume a low calorie diet.

OPSOMMING

'n Vergelykende analise van nutriëntverbruik en vleiskwaliteisparameters van Boerbokke en Suid-Afrikaanse Vleismerino's

deur

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Een van die hoofredes waarom die vraag na vleis die aanbod oorskrei, is die feit dat die mens tot op hede net op 'n paar dierspesies as bron van vleis gekonsentreer het. Benutting van nie-konvensionele spesies, soos bokke, kan aanbeveel word ten einde die globale vleisproduksie en -verbruik te verhoog. Ten spyte van die feit dat Suid-Afrika oor baie gedomestikeerde herkouerspesies beskik, is vleisverbruik in die verlede tot hoofsaaklik skape en beeste beperk. Bokke is tot 'n mindere mate gebruik. Dit kan gedeeltelik toegeskryf word aan die algemene siening dat bokvleis ondergeskik aan skaap- en beesvleis is.

Verskeie teenstrydighede ten opsigte van vergelykings tussen bokke en skape se groei, karkaseienskappe en vleissamestelling bestaan in die literatuur. Teenstrydige resultate ten opsigte van gemiddelde daaglikse toename (GDT), uitslagpersentasie, karkasgewig-verspreiding en organoleptiese eienskappe (veral taaiheid, sappigheid en geur) van diere afgerond onder intensiewe/voerkraal-toestande, kom veral voor. Hierdie projek is vervolgens uitgevoer ten einde meer inligting ten opsigte van die groei, karkas- en organoleptiese eienskappe, sowel as die chemiese samestelling van die vleis van Boerbok (BB) lammers in vergelyking met Suid-Afrikaanse Vleismerino (VM) lammers, onder voerkraal-toestande grootgemaak, te verkry.

Twee-en-dertig BB lammers en 32 VM lammers is vir hierdie studie gebruik. Al die diere is gekastreer en gespeen voor hulle in die voerkraal geplaas is. Twee verpilde diëte (gevoer aan 16 diere/spesie) met óf 'n lae (LE, 8.9 MJ/kg DM) óf 'n hoë (HE, 10.9 MJ/kg DM) metaboliseerbare energievlak is individueel, *ad lib,* vir óf 28 óf 56 dae aan die diere gevoer. Voer- en waterinname, GDT en voeromsettingsdoeltreffendheid (VOD) is gemonitor.

Gedurende die laaste week van die voedingsproef is 12 BB'e en 12 VM's gebruik ten einde die verteerbaarheid van die twee diëte te bepaal.

Na 28 of 56 dae is die diere geslag en die karkasse in Suid-Afrikaanse kommersiële snitte verdeel. Die *m. semimembranosus* en 8-9-10-rib snit van elke karkas is verwyder vir bepaling van chemiese samestelling, drupverlies, kookverlies, skeurwaardes en kleurbepaling. Die *m. gracilis* is uit die agterbeen uitgehaal en vir sensoriese evaluering gebruik.

VM's het betekenisvolle hoër GDT's as BB'e (bv. VMHE56: 0.281; BBHE56: 0.162 kg/dag) gehad. Binne 'n dieet was daar geen verskille (P>0.05) in VOD tussen BB'e en VM's nie en net die VM's se VOD het tussen die LE- en HE-dieet verskil (bv. BBLE28: 7.65; BBHE28: 6.37; VMLE28: 8.73; VMHE28: 5.56 kg voer/kg gewigstoename). BBLE het die droë materiaal (DM), ruproteïen (RP) en energie meer effektief verteer en het 'n hoër energieretensie as VMLE gehad. Die twee diëte het dieselfde ME-waarde vir die bokke gehad, wat bevestig dat bokke net so goed op 'n laer kwaliteit voer presteer as op 'n dieet van 'n hoër kwaliteit. Stikstofretensie is nie deur spesie of dieet beïnvloed nie. Die BB het 'n 49% laer (P<0.01) waterinname per kg massatoename op beide die HE- en LE-dieet gehad. Beide spesies het 'n laer (P<0.01) waterinname op die hoë as die lae energie dieet gehad. Verder het die BB ook 'n daaglikse waterinname van slegs 171 ml/kg$^{0.75}$ gehad in vergelyking met die 302 ml/kg$^{0.75}$ van die VM.

Die gewig van die lewer, leë pens, kop en pote (as persentasie van leë liggaamsgewig) was hoër vir bokke as vir skape. Die VM's se velle was betekenisvol swaarder, waarskynlik as gevolg van wolgroei. Beide niervet en kanaalvet het toegeneem met 'n toename in slagouderdom. Die diere wat na 56 dae in die voerkraal geslag is, het betekensivol langer en dieper karkasse gehad as dié na 28 dae. Binne 'n dieet en slagouderdom, het die skape breër en dieper (P<0.05) karkasse as die bokke gehad. BB'e het betekenisvol minder gewig per eenheid karkaslengte en dus maerder karkasse as VM's gehad. Dieet-energievlak het geen betekenisvolle effek op die verspreiding van karkasgewig by bokke gehad nie. VM's het egter swaarder karkasse (LE: 19.87 vs. 15.28 kg; HE: 24.01 vs. 17.05 kg) en proporsioneel swaarder ribbes en boude as BB'e gehad.

Dieet of slagouderdom het nie 'n betekenisvolle effek op die chemiese samestelling (vog, vet, proteïen en as) van die *m. semimembransous* gehad nie, maar VM's het laer (P<0.05) vogwaardes as BB'e gehad. In die 8-9-10-rib snit het BB'e betekenisvolle hoër vog en proteïen, maar laer vet- en energiewaardes as VM's gehad. In beide spesies het DM, vet en energiewaardes toegeneem met 'n toename in slagouderdom. BG'e het 'n betekenisvolle hoër konsentrasie in 11 van die 18 gemete essensiële aminosure in hul 8-9-10-rib snitte gehad in vergelyking met VM's. Bokkarkasse het ook hoër Ca, K, Mg, N en P-vlakke as skaapkarkasse gehad, ongeag die dieet. Daar was 'n neiging vir die bok *m. semimembranosus* om 'n laer Fe-inhoud as dié van die skaap te hê. BB-karkasse het 'n laer cholesterol-inhoud as skaapkarkasse (66.77 vs. 99.28 mg/100g, onderskeidelik) gehad. Palmitiensuur (C16:0), steariensuur (C18:0) en oleïensuur (C18:1n9) het die grootste proporsies van die vetsure in beide die *m. semimembranosus* en 8-9-10-rib snit van beide spesies uitgemaak. Op 'n LE-dieet was daar geen verskil tussen die versadigde (SFA) tot onversadigde (UFA) vetsuur-verhouding van bok- en skaapvleis nie. Op 'n HE-dieet het skaapvleis egter 'n betekenisvol hoër SFA:UFA-verhouding as bokvleis gehad (*m. semimembranosus*: 0.842 vs. 0.689; 8-9-10-rib snit: 1.40 vs. 0.892, onderskeidelik). Organolepties is 'n verskil tussen bok- en skaapvleis gevind. Elkeen het 'n spesifieke spesiegeur, wat onafhanklik van die dieet was. Bokvleis is waargeneem as meer veselrig as skaapvleis, maar daar was geen verskil in Warner-Bratzler skeurwaardes nie. In beide spesies het sagtheid afgeneem met 'n toename in ouderdom en daar was 'n neiging vir bokvleis om minder sappig as lamsvleis te wees. Bokvleis het ook 'n meer pertinente nasmaak as lam gehad. Geen objektiewe verskil kon tussen die kleur van gekookte skaap- en bokvleis onderskei word nie. Daar was egter 'n tendens vir vars lamsvleis om 'n hoër a*-waarde (rooiheid) as bokvleis te hê. Alhoewel dieet nie 'n invloed op drupverlies gehad het nie, het drupverlies toegeneem met 'n toename in slagouderdom. Slegs na 56 dae het die VM se *m. semimembranosus* 'n hoër (P>0.05) drupverlies as dié van die BB getoon (LE: 4.84 vs. 3.43%; HE: 4.72 vs. 3.32%, onderskeidelik). In die *m. semimembranosus* van beide spesies het kookverlies toegeneem met 'n toename in slagouderdom.

Aangesien dieet nie 'n effek op die groei, karkasgewig-verspreiding, waterhouvermoë, kleur, skeurwaardes of organoleptiese eienskappe van bokvleis gehad het nie, kan BB'e op 'n dieet met 'n laer ME-waarde as wat normaalweg vir skape geformuleer word, afgerond word, sonder om 'n verlaging in produksie te verwag. Dit mag 'n direkte ekonomiese voordeel vir afronding van BB'e in die voerkraal inhou. Vleis van jong voerkraalbokke is nie minderwaardig teenoor die van skape nie en dit het 'n hoër proteïen- en laer vetpersentasie. Dus kan bokvleis as 'n gesonde voedselbron gesien word, veral onder lae-inkomste groepe of mense wat 'n lae kalorie-dieet wil inneem.

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-Anonymous

CONTENTS

Language and style used in this thesis are in accordance with the requirements of the *Journal of the Science of Food and Agriculture*. This dissertation represents a compilation of manuscripts where each chapter is an individual entity and some repetition between chapters has, therefore, been unavoidable.

GENERAL INTRODUCTION

1. INTRODUCTION

Exploitation of unconventional livestock such as goats is advocated as a means of increasing global meat production and consumption (Babiker, El Khider & Shafie, 1990). Goat populations in developing countries represent 94% of the world total. Despite their numerical importance goat meat is little consumed and commands a low price compared to beef and mutton. This is attributed to a general belief that goat meat is inferior to mutton and beef (Babiker *et al.*, 1990).

In 2000, Africa had 22.8% and 29.1% of the total world's sheep and goat populations, respectively (FAO, 2001). Within the African society, sheep and goats comprise a greater proportion of the total wealth of poor families (Peacock, 1996) and are the primary source of meat and meat products. These flocks are raised under a wide variety of ecological zones and are able to survive and produce in harsh environmental conditions that are difficult for cattle to survive in (El Khidir, Babiker & Shafie, 1998).

When different countries are compared on the *per capita* consumption of red meat, South Africa was in 1967 one of the bigger consumers of both lamb and goat meat. The total meat consumption consisted of 20.8% mutton and lamb, 72.3% beef and 6.9% pork. In Table 1 it can be seen that the *per capita* consumption changed drastically since 1970, with mutton and lamb consumption decreasing from 9.6 kg to 3.6 kg in 2000. Chicken consumption increased dramatically to its current level of 19.4 kg where it even surpasses beef consumption (Hallowell, 2001).

Table 1. *Per capita* consumption (kg) of red meat, pork and chicken in South Africa (Hallowell, 2001)

Year	Beef	Pork	Sheep	Chicken
1970	24.5	3.5	9.6	5.3
1980	21.5	2.9	5.9	11.2
1991	18.1	3.4	5.3	14.4
2000	13.5	3.0	3.6	19.4

It is possible that the *per capita* consumption data of South Africa in the past only represented that of white consumers and that recent data is representative of all consumers. However, this decrease in red meat consumption is witnessed worldwide (Geay, Bauchart, Hocquette & Culioli, 2001). It is explained, at least in part, by the severe competition with white meats, the price of the latter being relatively low. However, it is also explained by the fact that consumers are concerned about health factors. This is largely due to statements from the medical profession that beef and mutton may contain too much saturated fat and trans-monounsaturated fatty acids, which can be major risks for the development of coronary heart disease. The decrease in meat consumption is also due to media events, for example boycotts of veal meat, illicit trading and use of hormones and "mad cow" disease (Geay *et al.*, 2001).

Table 2 shows the estimated number of sheep and goats in South Africa as 28.2 and 6.7 million, respectively (Hallowell, 2001).

Table 2. Cattle, sheep, goat and pig numbers in the various provinces in South Africa (Hallowell, 2001)

Province	Cattle	Sheep	Goat	Pig
Western Cape	492 000	3 114 000	248 000	245 000
Northern Cape	503 000	7 221 000	452 000	16 000
Free State	2 312 000	5 758 000	69 000	136 000
Eastern Cape	3 105 000	8 185 000	3 155 000	291 000
Kwazulu Natal	3 136 000	965 000	928 000	228 000
Mpumulanga	1 490 000	1 830 000	100 000	192 000
Northern Province	1 237 000	202 000	949 000	161 000
Gauteng	262 000	87 000	10 000	187 000
North West	1 844 000	804 000	803 000	211 000
Total	14 381 000	28 166 000	6 714 000	1 667 000

From July 1998 to June 1999, 4.6 million sheep, lambs and goats were slaughtered in South Africa. The total mutton production in South Africa was 104 400 t, while the mutton import was 49 800 t. The total consumption of sheep, lambs and goats was 153 000 t, while the *per capita* consumption was 3.6 kg (Agricultural Statistics, 2000).

According to USAID (1998) 30 579 goats were slaughtered in abattoirs in 1997. Unfortunately official statistics on goats slaughtered at abattoirs include Angora goats, and it is projected that most of the goats slaughtered are Angora goats. Relatively small quantities of meat-type goats are slaughtered by abattoirs. It seems as if goat slaughtering is negatively correlated to the mohair price (i.e. when the mohair price is high, less Angora goats are slaughtered and *vice versa*). Young goat (kid) meat is the most common type consumed in South Africa.

There appears to be good opportunities to produce value-added goat meat products, such as biltong, dried sausage, and chevon (goat meat) in combination with other meat in reconstituted products. James & Berry (1997) indicated that it is quite feasible to use chevon either alone or in combination with beef to produce low fat meat products with acceptable sensory characteristics to consumers who typically do not consume chevon products. However, both the nutrient and sensory qualities of these chevon products may be significantly influenced by both preparation and processing techniques. The potential of chevon to function as a source of lean meat that augments rather than dilutes product flavour has been demonstrated and can be applied to high-fat products such as hamburgers without any significant loss in sensory or nutrient qualities.

There are several intrinsic and extrinsic factors that influence growth, carcass traits, carcass mass distribution, composition and organoleptic qualities of goat and sheep meat. These factors will be discussed in the following few pages.

2. INTRINSIC AND EXTRINSIC FACTORS INFLUENCING GROWTH AND CARCASS TRAITS IN GOATS AND SHEEP

Growth can be defined as an increase in body weight until mature size is reached. This growth is an increase in cell size and cell numbers resulting in protein deposition. More specifically, growth is an increase in the mass of structural tissue (bone, muscle, and connective tissue) and organs accompanied by a change in body form and composition.
Development is defined as the directive co-ordination of all diverse processes until maturity is reached. It involves growth, cellular differentiation, and changes in body shape and form (Taylor, 1995).
Factors that influence growth and development in goats and sheep, include:

2.1 Stage of maturity and physiological state:
Pre-weaning growth of kids and lambs is invariably faster than post-weaning growth, even when abundant high quality feed is available after weaning and weaning is gradual (Louca, Mavrogenis & Lawlor, 1975; Mavrogenis, 1983). This difference is probably less an intrinsic effect of the degree of maturity of the animal than a consequence of lower assimilation of nutrients from solid feeds compared to milk. After weaning, growth of kids can remain linear until up to 1 year of age, provided that their diet and other environmental factors remain similar (Wilson, 1958a; Louca, Economides & Hancock, 1977). Intake increases with increasing body weight to compensate for increased maintenance requirements and the ratio of fat:lean in body gain (Warmington & Kirton, 1990). In one investigation, Morand-Fehr (1981) found that during the first 12 weeks after birth, Alpine kids weaned at five to six weeks, had an almost constant average daily gain (ADG) of 170 g/day, leaving out the weaning period. After that the daily weight gain decreased linearly to 75 g at week 30.
Heavier calves, lambs, kids and piglets have greater appetites and consume more feed in the post-weaning period than lighter animals. Their weight gain is therefore greater and feed conversion is more efficient since a greater proportion of the feed consumed is converted to body tissue rather than just simply used to maintain the animal.
Defined as the proportion of body weight which is converted into carcass, the interpretation of published data on dressing percentage is complicated by many factors including variation in gut contents resulting from different pre-slaughter fasting regimes, and the many definitions of what constitutes "the carcass" and "offals" (Warmington & Kirton, 1990). Dressing percentages of goats vary between 35% and 53%. While kids and lambs are consuming milk only, they are essentially monogastric and will have the highest dressing percentages because of the low level of gut fill. As kids start eating fibrous material, the rumen will develop and gut fill will increase - reducing dressing percentage. As the goat approaches maturity and

if fat is accumulated in the carcass, dressing percentage will again increase (Warmington & Kirton, 1990).

As in sheep and cattle, various body components of goats do not increase uniformly with body weight. Growth is centripetal, in the form of a "growth wave" which progresses from the extremities to the thorax and particularly to the dorso-lumbar area and breast (Wilson, 1958b; Morand-Fehr, 1981; Butler-Hogg & Mowlem, 1985). Thus, the allometric growth coefficients of head and feet relative to the whole body are less than 1 during the post-natal growth. The goat's breast, saddle and loin have the highest post-natal allometric coefficients relative to growth of the whole body (Sanz Sampelayo, Munoz, Lara, Gil Extrema & Boza, 1987) or of the carcass (Morand-Fehr, 1981; Butler-Hogg & Mowlem, 1985), which is similar to sheep carcasses (Thonney, Taylor, Murray & McClelland, 1987b). Butler-Hogg *et al.* (1987), as cited by Warmington & Kirton (1990) concluded that the musculature of sheep and goats differed in some respects, which is possibly related to the browsing behaviour of goats (*see #3: Carcass Mass Distribution of Goats and Sheep*). In sheep almost all non-carcass components (gut and contents, other internal organs, head, distal limbs, skin) are early maturing structures which form a progressively declining proportion of body weight as body weight increases (Kirton, Fourie & Jury, 1972; Thonney, Taylor, Murray & McClelland, 1987c) resulting in the carcass comprising an increasing proportion of body weight.

The body composition of goats changes markedly during growth. In female West African dwarf goats the proportion of body muscle increased from 32% to 46%, and bone decreased from 30% to 17% from birth until 13 kg body weight (Wilson, 1958b). The proportion of fat increased from 3.5% at birth to 15.5% at 10 kg, but then decreased slightly as kids approached sexual maturity. Ladipo (1973), as cited by Warmington & Kirton (1990) observed linear increases in the percentage lean and fat with body weight, and a decrease in percentage bone, in carcasses of dairy goats of 18-48 kg empty body weight.

In Boer goats (BG's) slaughtered up to 41 kg body weight (Naude & Hofmeyr, 1981), the muscle:bone ratio increased from 3.5:1 at 5 kg carcass weight to 5.3:1 at 23 kg, although total proportion of muscle in the carcass fell from 70% to 63% as a result of fat deposition. Only the South African Mutton merino (MM) equalled the BG in muscle proportion at the heavier carcass weight, while carcass muscle yields of Dorper and Merino sheep were less than 60% (Naudé & Hofmeyr, 1981).

Dissectible lean, fat and bone contents of entire male BG carcasses and lean:bone ratios at different carcass weights (Casey, 1982) can be seen in Table 3.

Table 3. Dissectible lean, fat and bone contents of male Boer goat carcasses, and lean:bone (L:B) ratios (Casey, 1982)

Carcass weight (kg)	Percentage Lean	Percentage Fat	Percentage Bone	L:B Ratio
4	70.0	9.2	20.8	3.37
12	68.1	17.8	13.8	4.93
17	64.5	21.8	12.6	5.12
22	63.3	24.1	12.0	5.28

Thonney *et al.* (1987a) concluded that although feral goats excelled in total muscle proportion relative to sheep (including the Oxford Down), their muscle weight distribution was much less attractive because goats had lower proportions of muscle in the higher priced cuts, at similar stages of maturity to sheep.

As the proportion of fat in the body (and carcass) increases with maturity, its distibution also changes. As in sheep (Butterfield, 1988) internal fat depots in goats tend to develop more quickly than carcass fat depots (McGregor, 1982). Subcutaneous fat is slow to develop in goats compared to sheep. Goat carcasses containing around 30% fat may have only 2.2-3.5 mm fat cover above the *m. longissimus dorsi* in the region of the tenth to eleventh rib (Naudé & Hofmeyr, 1981), but omental and mesenteric fat develop faster in goats (Thonney *et al.*, 1987c).

Kirton and Pickering (1967) showed that most differences in lamb carcass conformation were due to variation in amount and distribution of fat, which in turn was due partly to degree of maturity. Thonney *et al.* (1987b) observed that the maturing pattern of the total sheep carcass is influenced more by fat than by muscle or early maturing bone. This may also be true for goats, but this species has a low body fat content and lower carcass fat content relative to sheep and cattle at similar stages of maturity. Consequently, it is likely that the effects of fat in influencing conformation and proportional weight increases of different goat carcass regions are of less importance than in sheep and cattle (Warmington & Kirton, 1990).

2.2 *Nutrition:*

Finding enough of the right kind of feed is the most important general factor determining the development, dominance and survival of all living organisms. It is during lactation that nutrition of the ewe has the greatest effect on the growth rate and hence final meat production of its offspring (Rattray, 1992). In the first six weeks, the interaction of the factors determining the lamb's growth becomes complex. Milk intake has a large, though declining, effect on growth both directly and indirectly by influencing the pattern of increase in solid food intake which, although it commences at three weeks of age, only becomes significant after six to seven weeks. Lambs receiving less milk will eat more solid food if it is available (Treacher, 1979).

Louca *et al*. (1975) found that abrupt or early weaning can significantly depress subsequent growth for many weeks, although kids may eventually show compensatory growth given suitable conditions. In weaned Damascus kids, increasing the proportion of protein in the diet, on a DM basis, from 10.9 to 16.6% (Louca & Hancock, 1977) or 11.3 to 20.9% (Ash & Norton, 1987a) improves body weight gains. Increased growth is largely attributable to higher intakes of higher protein diets. McGregor (1985), as cited by Warmington & Kirton (1990), observed slower growth rates and greater fat deposition in goats fed high energy grain diets compared to pasture-fed contemporaries. Malik, Razzaque, Abbas, Alokhozam & Sahni (1996) found that although lambs fed a high (12.7 MJ/kg DM) energy diet ate less than the lambs fed a low (11 MJ/kg DM) or medium (11.9 MJ/kg DM) energy diet, the former were the most efficient in feed conversion (5.59 vs. 6.43 and 6.43, respectively).

Differences in the plane of nutrition at any age from the late fetal stage of maturity, not only alter growth generally but also affect the different regions, the different tissues and the various organs differentially. Thus, animals on different planes of nutrition, even if they are of the same breed and weight, will differ greatly in form and composition (Pomeroy, 1941). These workers showed that, when an animal is kept on a sub-maintenance diet, the different tissues and body regions are utilized for the supply of energy and protein for life in the reverse order of their maturity. Under such conditions fat is first utilized, followed by muscle and then by bone, and these tissues are first depleted from those regions in the reverse order of their maturity. Although fast rates of growth caused by a high plane of nutrition can lead to an earlier onset of the fattening phase of growth, the nature of the diet, not surprisingly, is also an important growth-regulating factor. Thus, when the protein:energy ratio is increased, the fastest-growing animals may become leaner (Campbell & King, 1982). Indeed, when the ratio is very high in protein the growth rate may be diminished (Campbell, Taverner & Curic, 1984). Since males have a higher protein:energy requirement than females, this factor can cause differences between the sexes in the composition of the carcasses when the energy intake, at a given ratio, is altered (Campbell & King, 1982).

Nutrition influences dressing percentage through variation in weight of gut contents and variation in actual organ weights. Ash & Norton (1987a) found that an increase in DM intake (*ad lib* vs. 75% *ad lib*) was associated with a lower dressing percentage. Increasing fibre content of the diet at the same DM intake is also likely to result in a lower dressing percentage, due to longer retention time in the digestive tract and thus a bigger gut fill. Black (1983) concluded that body composition reached at a constant weight can be manipulated by altering the level of food intake, and more so by the protein:energy ratio of the diet. Higher intakes tend to increase the ratio of fat:lean in body gain. The curvilinear relationship between protein:energy ratio and composition of body gain was described. Similar results can be expected on goats. It is important to realise that these relationships will not be as clear-cut in older, ruminating animals because microbial activity in the rumen can dramatically alter the ratio of protein:energy which is absorbed.

Goats receiving concentrate supplements (Wilson, 1960) or complete concentrate diets (McGregor,1985, as cited by Warminton & Kirton, 1990) increased their carcass fat deposition relative to browsing or grazing animals. Ash & Norton (1987b) found that Australian feral goats which consumed feed *ad lib* compared to 75% *ad lib* intake, contained more fat and less muscle in their empty bodies when slaughtered at the same weight. In contrast, varying diet composition between 11.3 and 20.9% crude protein did not affect final body composition. The authors attributed this result to similar ratios of protein:energy availability in the small intestine, as in Ash & Norton (1987a).

Nutritional regimes may influence fat distribution in the body. When slaughtered at 7.3 kg body weight, dwarf kids on a high plane of nutrition tended to have a higher proportion of total fat as abdominal and subcutaneous fat, and less as intermuscular fat, than kids on a low-plane diet (Wilson, 1960).

The amount of different fatty acids in goat fat is influenced by the level of nutrition and the composition of the feed. Increased milk intake in nursing kids leads to decreased saturation of adipose tissue fats, and increased proportions of fatty acids with odd carbon numbers and branched chains (Sauvant, Bas, Morand-Fehr, 1979, as cited by Warmington & Kirton, 1990). It is generally accepted that the fatty acid composition of adipose tissues in nursing kids depends on that of the milk (Muller, Sternhart & Scheper, 1985; Kuhne, Freudenreich & Ristic, 1986). Rumen hydrogenation of unsaturated fats in weaned kids lessens the relationship between fatty acid composition of feed and body fat (Morand-Fehr, 1981). Nevertheless, Gimenez, Baudino, Obeda, Molins De Pedernera & Gimenez (1986) observed higher iodine numbers and concentrations of unsaturated fatty acids in weaned kids supplemented with sunflower pellets compared to those fed lucerne hay only.

2.3 Sex and hormones

A most important aspect of genetic variability is that determining the balance of endocrine control of growth and development. Hormones are messenger substances that stimulate activity in various organs of the body. The word is derived from the Greek and means 'to stimulate or urge on.' Hormones are secreted in small quantities and yet exert profound effects. They act quickly, although not as quickly as nerve impulses.

Hormones are secreted by a number of glands (pituitary, ovary, testes, adrenal glands, pancreas, thyroid, kidney and uterus) that form the endocrine system, one of the two control systems of the body. The endocrine glands differ from other glands (such as salivary glands) because they secrete their active principle directly into the bloodstream. Hormones can have a very specific activity (for example, adrenocorticotrophic hormone (ACTH) that stimulates the adrenal cortex to produce adrenal cortical steroid hormones) or may have a generalized action (for example, somatotrophic hormone (STH) for body cell growth).

Hormones belong to three classes of chemical compounds.

- Amines, peptides and proteins. Hormones of this class originate in the brain (e.g. in the pituitary gland), the thyroid and parathyroid glands, the adrenal glands and the kidney.
- Steroids. Hormones of this class are formed primarily in adrenals, ovaries and testes.
- Fatty acids. Hormones of this class include the prostaglandins that are found in many tissues (Brander, 1986).

The muscles of male animals tend to be larger than the corresponding muscles in females; and castration in the male reduces the efficiency of weight gain in comparison with the entire animal. This is not merely a reflection of differences in overall body size. Sex is an important determinant of muscle growth. In this context, the involvement of the steroid hormones from the testis and ovary, and their interaction with hormones from the pituitary gland, the pancreas and the hypothalamus, has been elucidated over the past 30 years. Thus, in 1954 Burris, Bogard, Oliver, McKey & Oldfield, as cited by Lawrie (1998), demonstrated that male hormones (androgens) stimulated protein synthesis in cattle. Females tended to respond more to androgens than males, both in growth rate and feed conversion (Andrews, Beeson & Johnson, 1954).

Gonadectomy has long been used to facilitate control of male animals, and this practice is likely to continue. The removal of the testes, however, also eliminates the protein accreting (anabolic) benefits of the gonadal hormones; but this aspect can be restored by the administration of either male hormones (androgens) or female hormones (oestrogens). These anabolic agents are now applied to entire male and female animals as well as to castrates. The use of both androgens and oestrogens is believed to be necessary for maximum growth response (Heitzman, 1976). Anabolic agents include steroid hormones that are naturally present in the body, such as testosterone and oestradiol-17β, synthetic steroids such as trenbolone, and certain non-steroids such as diethylstilbestrol. Administration as removable implants is the preferred mode of usage.

β_2 Antagonists are substances that bind to β_2 receptors and thereby promote metabolism and are of particular interest in relation to meat producing animals. When β_2 antagonists, such as cimaterol, are included in the diet they cause a marked repartitioning between fat and protein whereby animals become leaner. The effect is achieved by increasing lipolytic action in adipose tissue and by reducing protein breakdown in muscular tissue (Buttery, 1983), whereas most other anabolic agents, including the sex hormones, act by a less selective increase of tissue components. However, β_2 antagonists have been said to cause a significant increase in toughness (Bailey, 1988 as cited by Lawrie, 1998).

Growth promoters are substances that are not nutrients in their own right. However, given in small quantities regularly in the feed or by implant, have an effect which leads to an increase in growth rate and/or feed conversion efficiency, and thus reducing the time taken for animals to reach the market, in animals fed a diet which is nutritionally adequate. The major growth promoters used in animal production are antibacterial, hormone implants which are usually mixtures of natural or synthetically produced hormone preparations, antibiotics or growth promoters which acts specifically in the rumen of cattle and sheep by improving rumen activity and the availability of propionic acid (Brander, 1986).

Within goats, buck kids grow faster than wethers, at least until they reach puberty (Louca *et al.*, 1977). Buck kids usually are 200 to 500 g heavier than does at birth (Mavrogenis, Constantinou & Louca, 1984). They also grow 10–15% faster to weaning than doe kids (Wilson 1958; Mavrogenis *et al.*, 1984; Nicol, 1985) and up to 30% faster than does during the immediate post-weaning period (Mavrogenis *et al.*, 1984). According to Ash & Norton (1987a), weaned buck kids fed high-energy diets grew 70% faster than doe kids, and converted feed to gain more efficiently.

Australian feral weaned buck kids dressed out three to four percent lower than doe kids relative to empty body weight (Ash & Norton, 1987b), but Kirton (1970) found no difference in mature New Zealand feral goats when based on full live weight. Louca *et al.* (1977) found no difference in the dressing percentages of sexually mature entire males and wethers. Misra, Kisore & Rawat (1986) observed a lower dressing percentage in entire males than in wethers, while Butler-Hogg & Mowlem (1985) found similar dressing percentages in female and wether Saanen and Angora goats (ranging from 14 to 46 kg live weight). Kirton (1970) found that in the New Zealand feral goat, bucks had heavier skins, heads and stomach contents than the does, which in turn had heavier stomachs, omental fats, livers, spleens, and lungs than the males when compared at 20 kg live weight. Female goat carcasses were fatter (10.6 vs. 6.0%) than those from male goats and correspondingly contained less protein and water. Male goats had heavier meat cuts in the fore quarters (neck, breast and shoulder) of the carcass and female goats had heavier cuts in the hind quarters. Wilson (1960) found similar results with the East African dwarf goats at two slaughter weights, namely 7.3 kg and 13.6 kg. These are typical features of sexual dimorphism which are also apparent in sheep (Thonney *et al.*, 1987c). Kirton (1970) also measured a higher proportion of flap in does than bucks. In comparison, Kirton, Carter, Clarke & Duganzich (1984) concluded that young female sheep dressed out slightly heavier than wethers (0.12 kg).

As in other meat species, bucks are leaner than does (Wilson, 1960; Kirton, 1970; Ash & Norton1987b) and wethers (Louca *et al.*, 1977; Owen, Norman, Philbrooks & Jones, 1978).

Ash & Norton (1987b) reported nearly twice as much dissectible carcass fat in does compared to bucks at both 10 and 20 kg empty body weight. Few studies have directly compared bucks, wethers and females under similar conditions, but McGregor (1985), as cited by Warmington & Kirton (1990), considered wethers intermediate in fatness between females and males.
Wilson (1960) found dwarf goat male empty bodies contained slightly more carcass muscle than females. For Australian Cashmere goats, Ash & Norton (1987b) observed a higher proportion of carcass muscle in bucks at 20 kg body weight, despite the two sexes being similar at 10 kg. This latter trend was largely due to increased fatness of doe carcasses. With Saanen goats, Colomer-Rocher & Kirton (1988), as cited by Warmington & Kirton. (1990), found the muscle content of buck carcasses remained around 60% from birth to maturity, whereas that of the female carcass declined from a similar initial level to just over 50% as fat content increased in mature does. Similar trends have been found for sheep with wethers intermediate (Butterfield, 1988).

2.4 Genotype:

Early maturing goat and sheep breeds reach their maximum potential for fat growth at a younger age and therefore they have a higher percentage fat and a lower percentage muscle and bone than late maturing breeds at a given live weight. Table 4 shows the carcass composition of four sheep breeds, and the BG, compared on a constant mass of 32 kg (Casey, 1982).

Table 4. Carcass composition of four sheep breeds and the Boer goat, compared on a constant mass of 32 kg (Casey, 1982)

Breed	Carcass composition (%)		
	Total fat	Bone	Muscle
SA Mutton merino	16.91	14.52	68.30
Merino	22.80	12.86	64.13
Dorper	23.98	12.41	62.97
Pedi	30.70	11.37	57.51
Boer goat	21.76	12.64	64.51

Growth rate is closely related to mature breed size. Goat breeds with a large mature size (females 50 kg or heavier) are capable of a pre-weaning growth rate higher than 200 g/day. These include the Swiss dairy breeds (Saanen, Alphine, Toggenburg), the South African Improved BG, the Damascus goat of the Mediterranean and the Serrana from Spain (Warmington & Kirton, 1990). Campbell (1977) as cited by Naude & Hofmeyr (1981) recorded

BG males and females growing at 291 g/day and 272 g/day, respectively. Warmington & Kirton (1990) gives the mature live weight of the BG buck as 115 kg, while the female BG's live weight can vary between 52 and 57 kg.

Naude & Hofmeyr (1981) reported dressing percentages of 49 to 52% in concentrate-fed male BG kids at 23 to 42 kg live weight. These were greater than or similar to dressing percentages of Merino, South African Mutton merino and Dorper sheep in the same trial. Warmington & Kirton (1990), however, concluded that dressing percentages of different goat breeds are similar, and may be slightly lower than those for sheep, partly because goats are leaner animals.

El Khidir *et al.* (1998) stated that, except for its slow growth rate, desert goats can yield heavier carcasses that are leaner, than desert sheep.

2.5 Environment

2.5.1 External environment

Among sheep it is found that those developed in temperate areas are generally of moderate size, of compact conformation and with short legs and a thick wool coat. In tropical areas sheep have long bodies, legs, ears and tails, and a coat of short hair rather than wool. In arid areas sheep frequently develop an enlarged tail (e.g. Van Rooy & Ronderib Afrikaner), where fat is stored - the metabolism of the latter offsets the environmental scarcity of water and food (Lawrie, 1998).

In general it is not the degree of heat alone which causes distress to animals in the tropics but its combination with humidity and the duration of these conditions. Twenty-one degrees Celcius provides a rough division between temperate and tropical stock, the latter functioning efficiently above this temperature (Wright, 1954).

Another factor to consider is that the energy requirement of animals grazing stubble may be 70% higher than those animals in a shaded feedlot. Therefore one consideration is whether to bale straw (and feed sheep or goats in feedlots) or allow direct grazing of the field. If the extra demand for energy (when animals are grazing stubble) has to be covered by feed supplementation, then the profitability of stubble grazing may be questionable (Landau, Perevolotsky, Bonfil, Barkai & Silanikove, 2000).

2.5.2 Maternal environment

Maternal handicaps can act pre-natally (birth rank and dam age) and post-natally (rearing ranks and dam age). The effects act via nutrient supply to the fetus or the young kid. These are essentially environmental effects (i.e. chance effects independent of the kids' genotypes) except that birth and rearing ranks depend to some extent on the dam's fecundity genes, some of which are passed on to the kids (Warmington & Kirton, 1990).

Single born kids are heavier than multiples, and the effect appears to be greater in larger breeds of a larger size. Differences of up to 1.2 kg result from competition for nutrients during pregnancy and are accentuated by competition for milk during the suckling period, so that multiples can be about 3.5 kg lighter than singles at weaning. Nicoll (1985) found that single born and reared New Zealand Angoras were 2.4 kg heavier than multiples at weaning. Birth rank effect in Damascus goats persisted to at least 140 days of age, when singles were 3.9 kg heavier than multiples at a mean body weight of 26.6 kg (Mavrogenis, 1983).

Dam age has less influence on birth weights and subsequent growth than on birth and rearing ranks, although there can be an interaction. Singles and twins born to yearling Australian feral does weighed 3.01 and 2.54 kg, respectively, while those born to adults weighed 3.01 and 2.83 kg (Pym, Holst & Nicholls, 1987, as cited by Warmington & Kirton, 1990). Thus, twins born to yearling dams were disadvantaged relative to their contemporaries born to older dams. The degree to which weaning weight changes with increasing dam age can depend on breed and environment. Weaning weight of New Zealand Angora kids increased with increasing dam age until the dams were at least three years old (Nicoll, 1985). However, Mavrogenis (1983) found that weaning weights of Damascus kids were similar for dams aged between two and seven years.

It was found that the weight of the dam (Table 5) has a stronger affect on the weight gain of the kids during the post-weaning period (third to seventh month) than during the second and third month (Romagosa Vila, 1975, as cited by Morand-Fehr, 1981).

Table 5. Average daily weight gain of female kids according to the adult weight of dams (g/day) (Romagosa Vila, 1975)

	Adult weight of dams (kg)		
Growth period (days)	30-40	40-50	55-60
30-90	128	143	148
90-200	118	138	147

3. CARCASS MASS DISTRIBUTION OF GOATS AND SHEEP

Owen & Norman (1977) reported differences in whole joint mass distribution between goats and sheep of various ages. In all indigenous goat castrates, ages ranging from milk tooth to full mouth, the fore quarter comprised about 50% of the carcass, whereas in sheep the proportion was about 44.5%. Joint proportions in milk tooth castrate goats and sheep were respectively the following: neck 10.2 and 9.0%, shoulder 20.2 and 16.3%, thorax 20.2 and 19.8%, loin 23.2 and 25.1% and leg 24.0 and 22.8%.

Table 6 shows the percentage carcass mass distribution between the five joints (fore limb, neck, ventral trunk, dorsal trunk and hind limb) of the BG in comparison to the MM, Merino, Dorper and Pedi on different slaughter masses (Casey, 1982).

No significant differences was calculated among the sheep and between the sheep and goat for the fore limb, neck and ventral trunk joints. No significant differences was found among the sheep regarding the dorsal trunk and hind limb joints. When the BG was included in the analyses, the F-value became highly significant for these two joints. The MM had the largest mass proportion in the fore limb and hind limb. In the Merino, the fore limb was slightly less than the MM, but the hind limb had the smallest mass proportion among the sheep. The Dorper had the second heaviest hind limb, followed by the Pedi. Although no significant differences was measured between the BG and the sheep in the mass proportion of the fore limb, ventral trunk and neck joints, the goat recorded a larger fore limb and ventral trunk than any of the sheep breeds. The dorsal trunk and hind limb joints were correspondingly less in the BG than in the sheep breeds.

In all instances distribution was greatest towards the hind limb followed by the ventral trunk, dorsal trunk, fore limb and neck respectively. In all instances the proportion in the hind limb, fore limb and neck decreased as growth proceeded, increased in the ventral trunk and remained virtually unchanged in the dorsal region.

Casey (1982) further studied the muscle, bone and fat distribution and concluded that sheep are only different due to their maturity type. At equal maturity, no real differences may be expected with the exception of fat distribution. He also stated that the goat is an entity differing from the sheep. Although highly significant differences were found in certain joints when the goat was included in the analysis of variance at similar slaughter masses, the differences became accentuated at similar degrees of fatness. The implication of these results, as concluded by Casey (1982), is that the goat must be dealt with as an entity in the market place and no comparisons ought to be made with lamb and mutton carcasses.

Table 6. Percentage carcass mass distribution in MM, Merino, Dorper, Pedi and BG (Casey, 1982)

Breed	Slaughter mass (kg)	Fore Limb (%)	Neck (%)	Ventral trunk (%)	Dorsal trunk (%)	Hind Limb (%)
MM	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
	avg	16.08	8.33	20.88	20.60	34.11
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	31.41
	41	14.95	8.32	25.96	20.85	29.92
	avg	16.01	8.78	22.87	20.73	21.56
Dorper	10	18.02	8.95	17.95	20.18	34.89
	23	15.51	7.77	22.71	21.22	32.78
	32	14.56	7.54	25.70	20.13	32.07
	41	13.70	7.40	27.52	19.98	31.30
	avg	15.45	7.92	23.47	20.38	32.78
Pedi	10	17.08	8.80	19.42	20.46	34.23
	23	14.94	8.08	23.99	20.59	32.39
	32	14.21	7.73	26.43	19.85	31.79
	41	13.50	7.42	29.67	19.43	29.98
	avg	14.93	8.00	24.88	20.08	32.00
BG	10	19.10	10.32	20.64	19.09	30.87
	23	17.31	8.97	25.48	19.37	28.88
	32	16.37	9.97	28.07	19.41	27.27
	41	16.33	9.15	28.90	19.22	26.42
	avg	17.28	9.33	25.77	19.27	28.36

4. COMPOSITION OF GOAT AND SHEEP MEAT

Internationally, the meat from sheep is either sold as lamb or mutton, while the meat from very young goats (eight to twelve weeks) is called cabrito and that from mature goats, chevon (Smith, Pike & Carpenter, 1974).

4.1 Proximate analysis

Distribution of fat is an important distinctive feature of goat meat when compared with mutton. Mature goats can contain 30% carcass fat or more, but this is unusual, and goat carcasses normally contain lower levels of total fat and less subcutaneous fat than sheep. Kirton (1970) reported a complete absence of subcutaneous fat in the loin of feral goats in New Zealand. Warmington & Kirton (1990) indicated that the level of intake and diet composition influence goat carcass composition and that high-energy feeds can increase fat deposition.

At similar slaughter weights, carcasses obtained from lambs fed a high energy diet (11.72 MJ ME/kg DM) had more kidney and pelvic fat than carcasses obtained from lambs fed a low energy diet (9.12 MJ ME/kg DM). Carcasses from lambs fed the high-energy diet had softer, yellower fat than carcasses from lambs fed the low energy diet. However, flavour scores were more intense for meat from lambs fed the low energy diet (Crouse, Busboom, Field & Ferrell, 1981).

Goats have a tendency to deposit most fat internally i.e. mesenteric, the renal tract and alimentary tract. This feature, together with the reduced deposition of subcutaneous fat makes goat meat leaner than mutton or beef. In terms of cost per unit of lean meat and in nutritional terms; goat meat is preferable over lamb, mutton, beef and pork (Naidu, 1996). Protein and ash content are similar in the meat from goats and sheep. Myofibrillar proteins and NPN, but not sarcoplasmic proteins, are similar in the muscles of goats and lambs (Babiker *et al.*, 1990). Differences in sarcoplasmic proteins might be due to species differences in muscle composition (Lawrie, 1998). The sarcoplasmic protein concentration of goat meat is significantly greater than that of lamb (Babiker *et al.*, 1990).

The moisture content of goat meat varies from 74.2 to 76.0%; protein 20.6 to 22.3%; fat 0.6 to 2.6%. The ash content is fairly constant around 1.1%. In general the composition of goat meat and mutton are comparable with respect to moisture, protein and ash contents (Thulasi & Ayyaluswami, 1983, as cited by Naidu, 1996).

Management factors affect the proximate composition of the meat (Naidu, 1996) and Owen *et al.* (1978) found that castrated goats had a higher proportion of fat in the carcass. The proximate analysis of raw goat meat in comparison to raw lamb (fat trimmed to 6.3 mm), can be seen in Tables 7 (USDA, 2001 a & b).

Table 7. Proximate analysis of goat meat in comparison to lamb (USDA, 2001 a & b)

Nutrient	Value per 100 grams of edible portion	
	Lamb	Goat
Water (g)	60.70	75.84
Energy (kJ)	1117.00	456.00
Protein (g)	16.88	20.60
Total Lipid (fat) (g)	21.59	2.31
Ash (g)	0.88	1.11

4.2 Mineral and vitamin composition

The information on mineral and vitamin content of goat meat is rare. Abdon *et al.* (1980) as cited by Naidu (1996) reported calcium, phosphorus, thiamine, riboflavin and niacin content in goat meat. The calcium content of goat meat is inferior to that of beef. Goat meat had a higher thiamin and riboflavin contents in the liver, but niacin was lower that that in beef (Naidu, 1996). The mineral and vitamin composition of raw goat meat in comparison with raw lamb (fat trimmed to 6.3 mm), can be seen in Tables 8 and 9, respectively (USDA, 2001 a & b).

Table 8. Mineral composition of goat meat in comparison to lamb (USDA, 2001 a & b)

Nutrient	Value per 100 grams of edible portion	
	Lamb	Goat
Calcium (mg)	12.00	13.00
Iron (mg)	1.57	2.83
Magnesium (mg)	22.00	n.m.[1)]
Phosphorus (mg)	160.00	180.00
Potassium (mg)	230.00	385.00
Sodium (mg)	58.00	82.00
Zinc (mg)	3.33	4.00
Copper (mg)	1.10	0.26
Manganese (mg)	0.02	0.04
Selenium (mcg)	19.80	8.80

[1)]nm = not measured

Table 9. Vitamin composition of goat meat in comparison to lamb (USDA, 2001 a & b)

Nutrient	Value per 100 grams of edible portion	
	Lamb	Goat
Vitamin C, ascorbic acid (mg)	0.000	0.000
Thiamin (mg)	0.120	0.110
Riboflavin (mg)	0.220	0.490
Niacin (mg)	6.100	3.750
Folate (mcg)	18.000	5.000
Vitamin B12 (mcg)	2.390	1.130
Vitamin A, (IU)	0.000	0.000
Vitamin A, (mcg_RE)	0.000	0.000
Pantothenic acid (mg)	0.670	n.m.[1)]
Vitamin B6 (mg)	0.130	n.m.[1)]
Vitamin E (mg_ATE)	0.210	n.m.[1)]

[1)]nm = not measured

4.3 Fatty acid composition and cholesterol content

Dietary cholesterol is an important issue of public health because of its relationship with the incidence of atherosclerosis. It is generally accepted that excessive fat consumption above a persons caloric needs is an important risk factor in cardiovascular heart disease (CHD), hypertension, stroke, diabetes and obesity.

Fatty acids are the most important lipid fraction. It has a particular role in the immune function, prevention of inflammation and as energy sources (Wan, Haw & Blackburn, 1989). The degree of saturation of fat, as determined by fatty acid composition, is one of the most important characteristics affecting its quality. Saturated fats solidify easily upon cooling and increase the hardness of the fat, thus affecting the palatability of the meat and consumer acceptability (Casey & Van Niekerk, 1985; Webb, Bosman & Casey, 1994). On the other hand the less saturated fats are easily oxidized leading to rancidity, and thereby influencing shelf life (Casey & Van Niekerk, 1985).

It is generally accepted that plasma cholesterol concentration is influenced by the fatty acid composition of dietary fat. High dietary levels of long-chain saturated fatty acids (SFA) increase plasma cholesterol levels in humans, compared with high levels of mono-unsaturated fatty acids (MUFA) and poli-unsaturated fatty acids (PUFA) (Grundy & Denke, 1990). However, not all SFA have equivalent effects. Lauric (C12:0), myristic (C14:0) and palmitic (C16:0) raise plasma cholesterol levels (Denke & Grundy, 1992; Sundram, Hayes & Siru, 1994; Tholstrup, Marckmann, Jespersen & Sandrom, 1994; Zock, De Vries & Katan, 1994), whereas stearic (C18:0) has no effect (Bonanome & Grundy, 1988; Denke & Grundy, 1992). Bonanome & Grundy (1988) reported that C18:1n9 (oleic acid) seems to decrease blood cholesterol content.

Duncan, Ørskov & Garton (1976) showed that, as in sheep, depot glycerides in goats contain an abnormally high proportion of odd-numbered n-fatty acids and methyl-branched fatty acids. Gaili & Ali (1985) reported that goats tended to deposit more fat in the omentum and mesentery than sheep. Goats tend to have a slightly higher proportion of oleic acid (C18:1n9) and less linoleic acid (C18:2n6) than sheep in all fat depots. The fatty acid and cholesterol composition of raw goat meat in comparison with raw lamb (fat trimmed to 6.3 mm), can be seen in Table 10 (USDA, 2001 a & b).

Table 10. Fatty acid and cholesterol composition of goat meat in comparison to lamb (USDA, 2001 a & b)

Nutrient	Value per 100 grams of edible portion	
	Lamb	Goat
Fatty acids, saturated (g)	9.470	0.710
10:0	0.060	0.000
12:0	0.100	0.000
14:0	0.870	0.030
16:0	4.750	0.330
18:0	2.980	0.330
Fatty acids, monounsaturated (g)	8.860	1.030
16:1	0.630	0.040
18:1	7.960	0.940
Fatty acids, polyunsaturated (g)	1.700	0.170
18:2	1.240	0.100
18:3	0.390	0.020
20:4	0.070	0.060
Cholesterol (mg)	72.000	57.000

4.4 Amino acid composition

The protein component and especially the amino acid profile are the most important component of goat meat. Goat meat contains more arginine, leucine and isoleucine than mutton. The pattern of the remaining amino acids is similar to that of mutton. Pork contains more histidine, lysine and methionine, threonine and valine than beef, chevon and mutton (Srinivasan & Moorjani, 1974). A comparison with the essential amino acid pattern of the ideal protein in Table 11 shows that goat meat is similar with respect to arginine, lysine, tryptophan, methionine and threonine. Goat meat contains 87.5, 60.4, 82.0 and 81.8% of the essential amino acids, histidine, phenylalanine, leucine, isoleucine and valine, respectively compared with the ideal reference protein. Goat meat is adequate with respect to all the essential amino acids (Srinivasan & Moorjani, 1974). The limiting amino acids are the sulphur containing amino acids followed by valine and isoleucine (Naidu, 1996). The amino acid composition of raw goat meat in comparison to raw lamb (with the fat trimmed to 6.3 mm), can be seen in Table 12 (USDA, 2001 a & b). Kansal *et al.* (1982) also found that the meat from castrated goats had significantly more pepsin and trypsin digestible proteins than that of intact goats.

Table 11. Amino acid composition (g/16g N) of meat samples (Srinivasan & Moorjani, 1974)

Amino acid	Chevon	Mutton	Beef	Pork	Ideal
Arginine	7.4	6.8	6.8	7.1	6.6
Histidine	2.1	2.8	3.0	3.4	2.4
Lysine	7.5	7.9	8.1	8.7	7.5
Tryptophan	1.5	1.4	1.4	1.3	1.6
Phenylalanine	3.3	3.3	3.4	3.6	5.8
Methionine	2.7	3.1	2.9	3.4	2.8
Threonine	4.8	4.6	4.5	5.2	5.0
Leucine	8.4	7.6	7.5	8.2	10.0
Isoleucine	5.1	4.6	4.5	5.4	6.6
Valine	5.4	5.5	4.9	6.0	7.0
Tyrosine	3.1	3.0	3.4	3.5	0.0
Cystine	1.2	1.3	1.1	1.1	0.0

Table 12. Amino acid composition of goat meat in comparison to lamb (USDA, 2001 a & b)

Nutrient	Value per 100 grams of edible portion	
	Lamb	Goat
Tryptophan (g)	0.197	0.306
Threonine (g)	0.723	0.981
Isoleucine (g)	0.815	1.042
Leucine (g)	1.313	1.716
Lysine (g)	1.491	1.532
Methionine (g)	0.433	0.552
Cystine (g)	0.202	0.245
Phenylalanine (g)	0.687	0.715
Tyrosine (g)	0.567	0.633
Valine (g)	0.911	1.103
Arginine (g)	1.003	1.512
Histidine (g)	0.535	0.429
Alanine (g)	1.015	n.m.[1)]
Aspartic acid (g)	1.486	n.m. [1)]
Glutamic acid (g)	2.450	n.m. [1)]
Glycine (g)	0.825	n.m. [1)]
Proline (g)	0.708	n.m. [1)]
Serine (g)	0.628	n.m. [1)]

[1)]nm = not measured

5. ORGANOLEPTIC QUALITIES OF GOAT AND SHEEP MEAT

Besides odour and taste, acceptability of meat is also influenced by colour, texture, tenderness and juiciness. According to Risvik (1994) tender and juicy meat is generally preferred by consumers. Tenderness and juiciness appear to decline with age in goats (Kirton, 1970; Gaili, Ghanem & Mukhtar, 1972) as in other animals, although Smith, Carpenter & Shelton (1978) reported this trend for tenderness but not for juiciness. Kirton (1970) showed little difference in flavour preference between the three ages (young, yearling, older) although Smith *et al.* (1978) identified a trend to slightly stronger flavours in older goats. However, Gaili *et al.* (1972) found no species difference in the flavour of lamb and goat meat, which is contradictory to the general concept that adult goats have strong flavoured meat which is rejected by consumers. The presence of 4-methyloctanoic (hircinoic) acid, in addition to other factors, contribute to the distinctive flavour in sheep and goat meat (Wong, Johnson & Nixon, 1975). Tenderness of meat depends on, among other factors, the amounts and states of three types of protein: the connective tissue (collagen, elastin, reticulin, mucopolysaccharides of the matrix), myofibrils (actin, myosin, tropomyosin) and sarcoplasm (sarcoplasmic proteins, sarcoplasmic reticulum). Although young animals have more connective tissue per unit weight in their muscles, it is largely elastine, while that found in older animals is collagen. Hence, younger animal's meat is more tender. In bovine muscle, the proportions of salt and acid-soluble collagen decrease with age as does collagen solubility on heating, while the degree of collagen molecule cross-linking increases (Lawrie, 1998). Similar trends can be expected in goats.

Toughness of goat meat is related to age at marketing, size of muscle fibres as well as muscle contraction, collagen content and solubility (Naidu, 1996). Although there is an indication that goat meat may be tougher than sheep meat from animals of similar age (Kirton, 1970), Naude & Hofmeyr (1981) determined only slightly lower collagen solubility in kid muscles when compared to lamb. Naude & Hofmeyr (1981) concluded that intrinsic differences in muscle tenderness between sheep and goats are unlikely, and that pre-slaughter animal treatment and post-slaughter carcass treatment are probably more important determinants of tenderness. In particular, the relatively low subcutaneous fat cover of goats can permit rapid cooling and consequent cold-shortening of muscles. Babiker *et al.* (1990) found no significant differences in the subjective evaluation of colour, juiciness, tenderness and overall acceptability of goat and sheep meat. Only flavour was significantly lower in goat meat than in lamb, possibly due to the fatness code. Goat meat is darker red in colour than lamb. It has significantly superior water-holding capacity and less cooking losses than lamb (Table 13). Meat flavour is significantly less strong in goat meat than lamb. However, Schönfeldt, Naudé, Bok, Van Heerden, Smit & Boshoff (1993) found that significant differences exist between the quality characteristics of sheep meat and Angora or Boer goat meat. Sheep meat had a more intense aroma, was more tender, contained less fibrous tissue residue and the species flavour is more pronounced (typical) than that of Angora and BG meat. In general, goat meat was found to be significantly different to sheep meat, the Angora to a lesser extent, however, than the BG.

Outdoor rearing of animals is different in many ways from indoor rearing. Animals reared outdoors often have a larger area to exercise in and have also the ability to select food and follow their natural pattern of behaviour. Animals reared outdoors in fields are exposed to several external factors like weather conditions such as rain and temperature fluctuations and have also other feed components available, which can influence the sensory quality of the meat (Jonsäll, Johansson & Lundström, 2001).

It is generally accepted that outdoor reared animals have tougher meat than their indoor reared contemporaries. However, Summers, Kemp, Ely & Fox (1978) found that tenderness, juiciness and shear values were similar for drylot and pasture fed lambs. Woodhams, Kirton & Jury (1966) found that fatter carcasses are not necessarily more tender. However, Schönfeldt *et al.* (1993) found that in goat and sheep meat the tenderness and species flavour of cooked cuts increased significantly with increasing fatness of carcasses.

Carlucci, Girolami, Napolitano & Monteleone (1998) found that both entire and castrated goats reared extensively were more tender and juicy than their entire counterparts, reared intensively. This finding may be attributed to the lower weight observed in extensively reared animals compared with intensively reared goats. Numerous authors (Whipple, Koohamaraie, Dikeman & Crouse, 1990; Koohamaraie, Shackleford, Wheeler, Lonergan & Doumit, 1995) have noted that a smaller area of muscle fibres, which is associated with lower weight animals, gives more tender meat. Therefore, when all attributes of eating quality, including odour, flavour and texture, are considered, higher quality can be associated with animals reared extensively. Thus, production systems based, at least partially, on pastures may be expected to produce goat meat that consumers prefer (Carlucci *et al.*, 1998).

Table 13. Water-holding capacity, colour parameters and shear force values of desert goat meat and lamb (Babiker *et al.*, 1990)

Parameter	Desert goat	Desert lamb
Colour L*	34.8[a]	36.2[b]
a*	13.1[a]	11.96[b]
b*	4.9[a]	5.7[b]
Cooking loss (%)	34.2[a]	36.6[b]
Shear force (kg/cm^2)	4.0	3.6

L* = Lightness; a* = Redness; b* = Yellowness

6. ADAPTATION OF GOATS AND SHEEP TO THEIR ENVIRONMENT

Under desert and tropical environments feed resources are restricted in quantity and quality. Therefore, differences among ruminants in energy requirements and digestive efficiency, which are reflected in the efficiency of the use of gross energy for production, are very important criteria for the selection of the most appropriate type of animal to be grown in any particular circumstances (Devendra, 1980). Silanikove (2000) concluded that goats living in harsh environments represent a climax in the capacity of domestic ruminants to adjust to such areas. Factors influencing this ability includes their small body size; low metabolic requirements; ability to reduce metabolism; digestive efficiency in relation to feeding strategies; efficiency of utilisation of high-fibre forage; efficient use of water; as well as their ability to economise the nitrogen requirements via urea recycling and nitrogen conservation. Therefore the reduction in metabolic rate helps desert ruminants cope with chronic energy shortages (Silanikove, 1986).

When a high percentage of herbaceous vegetation is present, sheep are preferred to goats for its utilization. This trend probably reflects the fact that sheep are better producers of meat in comparison to goats in respect of growth rate, feed conversion efficiency (FCE), and dressing percentage. Compared to the other four-footed farm animals, goats are generally not efficient meat producers. This is because they are traditionally raised under extensive (range) conditions, which include lack of feed and management, and their adaptation to normal production conditions relates more to survival than to production (Ensminger & Parker, 1986). Goats, however, utilise tannin-rich foliage better than sheep (Silanikove, Nitsan & Perevolotsky, 1994; Silanikove, Gilboa, Nitsan & Perevolotsky, 1996) through neutralisation of the antinutritional effects of tannins in the rumen (Silanikove *et al*., 1996).

When productive sheep are kept on depleted stubble, or the stocking rate is high, supplementation is needed to prevent impairment of body condition. This is not necessarily in goats, because when straw is given as the sole feed, N-recycling is more efficient in goats than in sheep (Tisserand, Hadjipanyiotou & Gihad, 1991). In addition, N-recycling is more efficient in goats originating from arid zones, such as the Bedouin Sinai goat, than in their counterparts from temperate regions, such as the Saanen (Silanikove, 1986).

7. FEEDING BEHAVIOUR OF GOATS AND SHEEP

Goats and sheep are mixed feeders. Goats, however, utilise a wider range of vegetation than sheep (Malachek & Provenza, 1981, as cited by Santra, Karim, Mishra, Chaturvedi & Prasad, 1998), and therefore have an ability to survive on sparse vegetation (Gall, 1981). Goats also have a better nutrient utilisation efficiency on poor-quality feed (Singh & Bhatia, 1981, as cited by Santra *et al.*, 1998). Both goats and sheep are considered more capable of selective feeding than cattle because of their cleft upper lips (Hafez, 1975).

Goats carefully select their forage during grazing, balancing nutritional requirements and avoiding toxic materials (Provenza, 1995). Goats prefer shrubs and bushes to grasses when compared with other small ruminants. Sheep seem to prefer grazing to browsing (Genin & Pijoan, 1993). In a mixed Mediterranean environment, browse represents at least 40% of a goat's diet (Landau *et al.*, 2000). However, other studies have demonstrated that when disposability fluctuates in shrub land, goats are 50% grazers and 50% browsers (Rios, 1983, as cited by Morales, Galina, Jimenez & Haenlein, 2000). Behavioural research has shown that grasses comprised 92% of the goat diet in summer whilst shrub land and forbes were the key nutrient sources in winter (Coblentz, 1977). In contrast, Trujillo & Garcia (1995) showed insignificant utilisation of grasses and cacki by grazing goats. However, Galina, Puga, Hernádez & Haenlein (1998) demonstrated that goats are opportunistic browsers or grazers, depending on the availability and quality of forage. Santra *et al.* (1998) found that the predominantly browsing and highly selective feeding behaviour of goats are limiting factors in their utilisation in stall feeding. These attributes can lead to variation in their feeding behaviour as well as influence their food selection and performance under such conditions.

8. DIGESTION IN GOATS AND SHEEP

Studies conducted on the comparison of performance of sheep and goats on low-grade roughage (3.85% crude protein (CP); 34.65% crude fibre (CF); 1.32% ether extract (EE)) (Sharma & Rajora, 1977), forage diets (8.1-17.8% CP; 22.3-33.7% cellulose; 18.33-19.75 MJ gross energy (GE) per kg DM) (Jones, Larsen, Javed, Conefer & Gaudreau, 1972), aquatic macrophytes (9.21% CP, 40.32% acid detergent fibre (ADF), 1.95% EE and 19.5 MJ GE per kg DM) (Adebowale, 1988) and crop residues (4.64-9.06% CP; 32.0-63.72% neutral detergent fibre (NDF); 21.0-42.63% ADF, 17.23-19.04 MJ GE/kg DM) (Aregheore, 1996) have indicated that the two species have a similar digestive efficiency on good-quality feed, whereas goats perform better than sheep on low-grade roughage. Better nutrient utilisation in goats than in sheep on low-grade feeds could be ascribed to their efficient fibre digestion (Aregheore, 1996; Gihad, El-Bedawy & Behrez, 1980). It has also been established that rumen protozoa play a significant role in fibre digestibility since fibre digestibility is sizeably reduced in defaunated animals (Ushida & Jouany, 1990; Chaudhary, Shrivastava & Singh, 1995). Morales *et al.* (2000) found that goats adequately supplemented with small amounts of essential nutrients performed equally well on lower digestibility feeds as their contemporaries on higher ones. Digestibility and intake were apparently improved, due to elevation of rumen pH and augmentation of degradable bacterial synthesis from supplementation with essential amino acids, NPN, sulphur and phosphorus, which improves cellulose utilisation. Morales *et al.* (2000) also concluded that the goat's rumen adapts fast to new dietary conditions to produce bacterial protein and therefore maintain milk production in the ewe. Al-Nakib, Al-Shukaily, Al-Hanai & Al-Nabhani (1996) concluded that sheep are more responsive than goats to a better environment and are therefore more efficient in utilising it.

Although the total gut length in sheep and goats are the same (Sisson & Grossman, 1975), the retention time of digesta in the goat's rumen is higher than in that of the sheep (Devendra, 1971, as cited by Santra *et al.*, 1998; AFRC, 1998) which could also contribute to the fact that digestibility of nutrients in goats is better than in sheep. Studies by Watson & Norton (1982) and Domingue, Dellow & Barry (1991) showed rumen fluid volume in relation to live weight to be higher in goats than is sheep. This could explain why goats seem able to consume more digestible organic matter (OM) than sheep, without having higher rates of passage or faster rates of digestion (AFRC, 1998).

Adebowale (1988) found a better ADF digestibility in goats than in sheep. This difference was possibly attributed to the explanation that goats pass larger particles through their alimentary tract than sheep with the capacity of the digestive system of goats proportionately greater than that of steers and sheep. High water consumption, which promotes faster rumen washout and hence a faster passage, may be responsible for the lower digestibility in sheep (Koes &

Pfander, 1975). Increased water intake may also dilute bacterial populations, hindering substrate-enzyme contact (Baker & Harris, 1947).

It can be concluded that it appears as if goats and sheep have similar capacities to digest forages of medium to high digestibility (OM digestibility >60%). When fed on low-quality roughage without supplementation with nitrogen, goats are likely to have an advantage over sheep in being able to maintain digestibility, possible due to a higher concentration of rumen ammonia.

An important consequence is that conventional feeds (i.e. excluding low-quality roughage fed without N supplements) are likely to have the same digestible energy value (DE), and presumably ME value for both sheep and goats (AFRC, 1998).

9. FEED INTAKE & PRODUCTION OF GOATS AND SHEEP

Sormunen-Cristian & Kangasmäki (2000) found that total daily dry matter (DM), net energy and protein intake/kg$W^{0.75}$ of lambs from the age of two months to slaughter were significantly higher than that of kids. In the study of Lu (1988), DM intake of goats ranged from 1.5 to 5.2% of body weight (BW). Sormunen-Cristian & Kangasmäki (2000) compared the performance of Finnish Landrace lambs and goats raised under stall-feeding conditions and found that mean total DM intake (98 vs. 75 g/kg$W^{0.75}$) and mean growth rate (245 vs. 174 g/animal/day) were higher for lambs than for kids. Similar results were obtained by Murthy, Reddy & Reddy (1995). Santra *et al*. (1998) also concluded that under controlled feeding, DM intake is lower (57.1 vs. 62.1 g/kg$W^{0.75}$) while digestibility of the organic matter (OM), NDF and ADF are higher in goats compared to that of sheep, which could partly be due to the higher number of total ciliate protozoa as well as *holotrichs* and *spirotrichs* in the rumen medium of goats.

One of the most favourable attributes of goats as meat-producing animals is their high rate of reproduction (Naudé & Hofmeyr, 1981). A study of world literature shows that most goat breeds have average litter sizes of approximately 1.5 and higher as a result of high twinning rates; triplets and quadruplets are also frequent (Devendra & Burns, 1970). The goat is the most prolific of all domesticated ruminants under tropical and subtropical conditions (Naudé & Hofmeyr, 1981).

In comparison to their high prolificacy, the growth rate of meat goats is considerably lower than that of sheep. For example, goats grow 150 to 230g per day, while sheep grow 300 to 400g per day on a similar diet. Poor feed conversions are often due to low growth rates, which in turn, may be due to poor nutritional conditions as well as to limited genetic potential. Ensminger & Parker (1986) found in lambs that when the growth rate increases, the feed conversion also improves. This may be similar in kids (Ensminger & Parker, 1986). On the other hand, in the study of Sormunen-Christian & Kangasmäki (2000), the dressing percentage (48.2 vs. 42.6%) and DM utilisation (kg/kg meat) were higher in kids than in lambs. Kids, however, needed two months longer than lambs to produce an 18 kg carcass (202 vs. 143 days). These authors also found that as lambs grew, their feed intake increased linearly whereas that of kids fluctuated markedly and they even showed a lack of appetite on several occasions. It was suggested that the inappetence in the kids partly resulted from a fall in their rumen pH caused by intensive concentrate feeding (Forbes, 1995). Although nutritive value of refusals was not assessed, the kids appeared to be more selective feeders than lambs. In the study of Wahed & Owen (1986) goats were able to show selective feeding even when offered a morphologically homogenous feed such as straw. Feed selection is found especially when the goat is grazing or browsing (McCammon-Feldman, Van Soest, Harvatly & McDowel, 1981, as cited by Sormunen-Cristian & Kangasmäki, 2000).

10. WATER INTAKE OF GOATS AND SHEEP

The ability of goats to survive and even reproduce under adverse environmental conditions was possibly one of the reasons why goats were among the first animals domesticated by man for the production of meat, milk, skin and fibre (Gall, 1981). Limited water availability is a major factor influencing the productivity of ruminants in desert and tropical regions (Shkolnik & Silanikove, 1981). A hot environment reduces the voluntary food intake and increases the feed utilization of ruminants (Silanikove, 1992). As DM and water intake are linearly related to each other (Macfarlane & Howard, 1972; Silanikove, 1987), water restriction or dehydration therefore reduces voluntary feed intake (Balch, Balch, Johnson & Turner, 1953; Silanikove, 1985). Breeds of ruminants that are well adapted to a desert environment demonstrate a greater capability to ameliorate the stressful effects induced by water deprivation (Maltz *et al.*, 1984) and therefore maintain higher feed intake and productivity, than non-desert breeds. According to Devendra (1980), Narjisse (1991) and Tisserand *et al.* (1991), goats are adapted to water shortages and are efficient users of water. Alam, Pappi & Sykes (1983) observed lower water intake for goats than sheep, while Wahed *et al.* (1986) reported sheep and goats to consume 2.44 and 2.05 kg water/kg feed DM, respectively. Therefore it seems as if goats can survive with less water than most sheep breeds and thus are a more suitable choice for production under arid conditions.

11. THE SOUTH AFRICAN BOER GOAT:

The South African BG has its origin in the Eastern Cape Province and evolved from indigenous African and introduced European stock (Casey & Van Niekerk, 1988). In the late 1920's and early 1930's a few breeders began using a distinct breeding policy. Their goal was to improve the conformation of the goat and to breed a goat that would be able, firstly to utilise bush and shrubs, and secondly, to produce more quality meat. Although these were the primary objectives, the breeders also concentrated on good mothering ability, high productivity and hardiness (South African Livestock Breeding, 1998).

The Boer Goats Breeders' Society was founded on 4 July 1959. This fulfilled the need for an authorised body to improve and protect the interests of BG breeders. The breeding standards include the roman-shaped head with strong jaw, the slight dip behind the shoulders, the slightly drooping rump, white colour with red head and blaze, pigmented skin and four sound strong legs (Casey & Van Niekerk, 1988; South African Livestock Breeding, 1998).

BG are hardy, graze a wide spectrum of plants, grasses and shrubs, effectively combatting bush encroachment, have low water turnover rates and low internal parasite infestation (Casey & Van Niekerk, 1988). BG's are inclined to forage from the top down-wards, from heights of 160 cm to 10 cm (Aucamp & Du Toit, 1980) and have been found to consume a ratio of 82% bush and 16% grass (Viljoen, 1980). Bush encroachment and regrowth has been combatted successfully with BG's (Du Toit, 1972), who browse leaves but also debark stems and branches, particularly of young plants. The practice of using goats in bush control has been successful internationally (Provenza, Bowns, Urness, Malachek & Butcher, 1983). Neither veld conservation practices, nor veld burning, nor planned pasture management with cattle has equalled the impact of goats in combatting bush encroachment (Aucamp, 1979; Tainton, 1981). This is an economically important trait of goats. Foraging habits may contribute to BG's having low infestations of internal parasites (MacIvor & Horak, 1984).

In the late 1960's the South African Department of Agriculture conducted production and reproduction trials on the BG. This research concentrated on the grazing ability of goats on pastures consisting of both grass and shrubs. The paddocks grazed by goats showed an improvement of 58% in terms of grass coverage over a four-year period and those grazed by sheep a decrease of 18%. The shrubs were well controlled and kept down to a reasonable height (South African Livestock Breeding, 1998). Over a period of twenty years the productivity of a flock of 200 ewes, on natural vegetation with an average annual rainfall of 450 mm, were measured and the results can be seen in Table 14.

Table 14. Productivity of the Boer goat (South African Livestock Breeding, 1998)

Ewes kidded per number of ewes mated (%)	90
Kids born per number of ewes kidded (%)	210
Kids weaned per number of ewes kidded (%)	165
Weaning mass at 120 days (kg)	29

The BG is a limited seasonal breeder and mating can be done at a time to ensure that there is enough food available at kidding. Due to the BG's high fertility (Table 14), the mating period can be kept as short as possible (approximately 6 weeks). Scanning to identify triplets and quadruplets allows the breeder to take care of the multiple births by supplementing the relevant ewes before and after kidding (South African Livestock Breeding, 1998).

Gipson (2000) reported results obtained in an annual meat buck performance test of 70 days at Langston University, in cooperation with the Oklahoma Meat Goat Association (OMGA). The animals were between two and five months when they entered the trial and after a 14 day adjustment period, thy commenced a 70 day performance test. The test was open to purebred and crossbred bucks. Out of the 47 animals that participated in this test, six were Boer-crosses and 40 were purebred BG's. The average test statistics for 1999 can be seen in Table 15.

Table 15. Initial and final live weight, weight gain, ADG, cumulative feed intake and feed efficiency of 47 tested BG's and BG-crosses (Gipson, 2000)

Initial live weight (kg)	29.48
Final live weight (kg)	44.45
Weight gain (kg)	14.97
ADG (kg/day)	0.236
Cumulative feed intake (kg)	110.86
Feed efficiency (kg feed/kg weight gain)	7.37

This breed is very adaptable and is successful on extensive grazing as well as on intensive pastures. During the past few years the South African BG has been exported all over the world. The demand for this breed is growing rapidly, especially for crossbreeding programmes improving other breeds.

The potential of the BG as a meat-producing animal has been recognised by early researchers such as Owen & Norman (1977) and Casey (1983). However, little is known about the performance of goats under intensive feedlot conditions. Growth rates of BG's are generally lower than sheep (Gall, 1981), but under favourable nutritional conditions, weight gains of more than 200 g per day can be obtained, compared to maximum values of 176 g per day under extensive subtropical conditions (Van Niekerk & Casey, 1988). In general, the poorer growth rate of goats in comparison to sheep may be due to the fact that their nutrient requirements differ and traditionally, goats are reared on diets formulated for sheep (Naudé & Hofmeyr, 1981). Poor performance of goats in the feedlot, in comparison to sheep, may be ascribed to the fact that goats have a lower intake of concentrate diet. A second explanation might also be the extra activity of the goat, which increases its energy expenditure and lowers its feed intake (Naudé & Hofmeyr, 1981). The BG has also adapted to survive under extensive conditions in dryer areas of South Africa and grazes and browses a different spectrum of plants than sheep; a characteristic that favours combined species grazing (Aucamp & Du Toit, 1980). It also seems as if the BG can survive with less water than most sheep breeds.

The South African BG has an important role to play in combatting the predicted global shortage of red meat (South African Livestock Breeding, 1998).

12. THE SOUTH AFRICAN MUTTON MERINO

The South African Mutton merino (MM) is a dual-purpose breed, developed to produce a slaughter lamb at an early age, as well as good quality wool. The breed is known for its high fertility. Lambing percentages of 150% and higher are quite common. The MM fits in well with an eight-month breeding cycle, hence three lamb crops may be produced every two years. In this manner lambing percentages of 250% have been achieved (South African Livestock Breeding, 1998). The MM is also adapted to most environmental conditions in South Africa and has good mothering abilities. The MM is a polled sheep and its good conformation, hardiness, fertility and adaptability ensure that rams are popular for cross breeding purposes with other woolled sheep breeds in order to produce better slaughter lambs without contamination of the wool clip. Embryos are also exported to Australia (South African Livestock Breeding, 1998).

This breed has contributed to the development of three other breeds in South Africa, namely the Dormer, Dohne merino and Afrino. Due to the many animals available in South Africa, a high selection pressure can be maintained in order to improve the South African flock. A feed conversion ratio of 3.9:1 has been achieved in finishing MM lambs (South African Livestock Breeding, 1998). It has an average live weight of 35 kg at 100 days under natural conditions and mature ewes have an average live weight of 70-80 kg and rams 100–110 kg (Latsky, 1993).

Ewes can yield as much as 4.8 l of milk per day and are therefore able to rear multiple offspring with high weaning weights. Due to the fact that fat deposition only occurs at a much later age, slaughter lambs obtain the best grading possible even up to carcass weights of 27 to 28 kg. Ewes produce an average of 3.4 to 4.5 kg wool and rams between 4.5 and 6.0 kg. The clip is a medium to strong white wool, which is over-crimped in comparison to Merino wool of the same strength. MM wool measures on average between 22 and 23 microns without kemp or coloured fibres (South African Livestock Breeding, 1998).

The dry matter intake (DMI), average daily gain (ADG) and feed conversion efficiency (FCE) for MM ram and ewe lambs, reported by Brand & Van der Merwe (1993), can be seen in Table 16.

Table 16. DMI, ADG, FCE and days in the feedlot for MM ram and ewe lambs (growth interval ca. 25 kg to ca. 40 kg), fed grain enriched mixtures (Brand & Van der Merwe, 1993)

Parameter measured	Rams	Ewes
Total DMI (kg)	1280	1206
ADG (g/day)	239^a	190^b
FCE (kg feed/kg weight gain)	5.44^a	6.39^b
Days in feedlot	66^a	81^b

^{a,b,c} Means in the same row with different superscripts differ (P<0.05)

The MM is an efficient feed converter and popular in feedlot production systems. It is able to utilize low quality roughage and is non-selective in its grazing habits. Due to the grazing habits of the MM, it is efficient in energy utilisation, which leads to increased wool and mutton production. The breed is therefore very popular in the grain producing areas of South Africa. The breed excels under all climatic conditions and is known for its strong constitution. Its adaptability to a wide variety of environmental conditions has been a major factor in its popularity (South African Livestock Breeding, 1998).

13. AIM OF THIS STUDY

It can therefore be seen that numerous contradictions regarding comparative goat and sheep growth, carcass characteristics and meat composition still exist in the literature. Concepts involved with most of the contradictions includes ADG, dressing percentage, carcass mass distribution and organoleptic characteristics, especially tenderness, juiciness and flavour, particularly as pertaining to animals reared/grown under intensive conditions. Therefore this project was undertaken to obtain more information on the growth, carcass and organoleptic characteristics, as well as meat chemical composition of BG's in comparison with South African MM's, under feedlot conditions.

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PRODUCTION EFFICIENCY OF SA MUTTON MERINO LAMBS AND BOER GOAT KIDS RECEIVING EITHER A LOW OR A HIGH ENERGY FEEDLOT DIET

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ABSTRACT

Individual food consumption, utilisation, digestion efficiency and growth of 32 weaned Boer goat (BG) kids and 32 South African Mutton merino (MM) lambs were investigated. Two pelleted diets (fed to 16 animals/species) with either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) metabolisable energy level were fed individually, *ad lib*, for either 28 or 56 days. MM's had significantly higher average daily gains (ADG) than BG's. Within a diet there was no significant difference in feed conversion efficiency (FCE) between BG's and MM's and only the MM's FCE differed between the LE and HE diet. BGLE digested DM, CP and energy more efficiently and had a higher energy retention than MMLE. Neither species, nor diet affected nitrogen retention. Boer goats may be finished on a diet with a lower ME-value than that usually formulated for sheep, without a reduction in performance. These results may render the BG economically viable for feedlot finishing.

Key words: feed efficiency, digestibility, diet energy content.

INTRODUCTION

In 2000 Africa had 22.8% and 29.1% of the total world's sheep and goat populations, respectively (FAO, 2001). Within the African society, sheep and goats comprise a greater proportion of the total wealth of poor families (Peacock, 1996) and are the primary source for meat and meat products. These flocks are raised under a wide variety of ecological zones and are able to survive and produce under harsh environmental conditions that are difficult for cattle to survive in (El Khidir, Babiker & Shafie, 1998). Under desert and tropical environments, feed resources are restricted in quantity and quality. Therefore differences among ruminants in energy requirements and digestive efficiency are very important criteria for the selection of the most appropriate type of animal to be kept in any particular circumstance (Devendra, 1990, as cited by Silanikove, 2000).

Studies conducted on the comparison of performance between sheep and goats on low-grade roughage (Sharma & Rajora, 1977), forage diets (Jones, Larsen, Javed, Conefer & Gaudreau, 1972), aquatic macrophytes (Adebowale, 1988) and crop residues (Aregheore, 1996) have indicated that the two species have a similar digestive efficiency on good quality feed, whereas goats perform better than sheep on low-grade roughage. This could be ascribed to their more efficient fibre digestion (Aregheore, 1996; Gihad, El-Bedawy & Mehrez, 1980). Morales, Galina, Jimenez & Haenlein (2000) found that the goat's rumen adapts fast to new dietary conditions to produce bacterial protein.

The potential of the Boer goat (BG) as a meat-producing animal has been recognised by early researchers such as Owen & Norman (1977) and Casey (1983). However, little is known about the performance of goats under intensive conditions. Growth rates of BG's are generally lower than that of sheep (Gall, 1981), but under favourable nutritional conditions, weight gains of more than 200 g/day can be obtained in goats, compared to maximum values of 176 g/day under extensive subtropical conditions (Van Niekerk & Casey, 1988). The poorer growth rate of goats in comparison to sheep may be due to the fact that their nutrient requirements differ and traditionally, goats are reared on diets formulated for sheep (Naudé & Hofmeyr, 1981). According to Gaili & Ali (1985) the fact that goats have a lower intake of concentrated diet in comparison to sheep, may lead to their poor performance in the feedlot.

Nutrient requirements are well defined for cattle and sheep, but a lack of reliable information about the nutritional needs of goats, especially those raised under intensive conditions, still exist (Sormunen-Cristian & Kangasmäki, 2000). Therefore, in this investigation, goat kids were fed according to the energy and protein recommendation for lambs (NRC, 1985), although information is insufficient as to whether protein and energy requirements for other ruminants are applicable to goats.

The South African Mutton merino (MM) was selected as a standard to compare to the BG in this investigation. The MM is a dual-purpose breed, developed to produce a slaughter lamb at an early age. It has a high fertility, good conformation, good feed conversion ratio and adaptability and is therefore popular in feedlot production systems. Due to species and environmental differences, the weaning age and weight of BG's differ from that of the MM's in this investigation. With the start of this experiment, the BG's were 135 days and the MM's 90 days of age, which represents the actual weaning age of the animals as well as the age at which they would enter a commercial feedlot. The economy of a feedlot requires that animals be slaughtered at a targeted weight or after a certain number of days in the feedlot. In this experiment, this duration was either 28 or 56 days.

A question that arises is whether goats can be finished in a feedlot in a similar fashion to lambs, and if so, on what type of feed and for what period of time. Since little is known about the performance of goats in the feedlot, this study was conducted to determine the influence of dietary energy levels and duration in the feedlot on the feed intake, efficiency of utilisation, digestion as well as growth parameters of the BG kid in comparison with the MM lamb.

MATERIALS AND METHODS

Thirty-two BG kids and 32 MM lambs were used in this investigation. All the animals were castrated and weaned prior to entering the feedlot. The average initial body weight of the kids and lambs were 26.23 ± 3.86 kg and 32.72 ± 2.13 kg, respectively. The animals were randomly allocated to four treatment groups of eight animals per species and housed individually in an enclosed but adequately ventilated shed with a slatted floor. The individual pens were built of a material that allowed adjacent animals so see and interact with each other. The two main treatments within species, were a high (HE) and low (LE) metabolisable energy diet. Within the energy diet treatments the animals were slaughtered at either 28 or 56 days. The pelleted diets (Table 1) were formulated according to the NRC (1985) recommendations for lambs, on an isonitrogenous basis (14.4% crude protein (CP) on a DM-basis) to contain either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) calculated metabolisable energy level. The animals received the diets and water *ad lib*. Lambs and kids were fed twice daily and orts were collected daily, pooled and the pooled weight determined weekly. The animals were also weighed weekly.

After 28 days, 16 BG's and 16 MM's, 8 animals/species on the LE or HE diet respectively, were slaughtered, while the rest of the animals continued in the trial until day 56 when they were slaughtered. Feed intake, average daily gain (ADG), feed conversion efficiency (kg feed/kg weight gain) (FCE) and dressing percentage (from cold carcass weights) were calculated for each animal. Dressing percentage was calculated from cold carcass weight as a percentage of live weight and also as a percentage of empty body weight (EBW) by removing the stomach and intestine content after slaughter.

During the last week of the feeding trial, 12 BG kids and 12 MM lambs were used to evaluate the digestibility of the two diets. Total collection of faeces and urine were conducted twice daily. Twenty ml of urine preservative (80 g potassium dichromate and 20 g mercuric chloride dissolved in 1 l distilled water) was added each morning to the urine collection jugs to prevent volatilization of ammonia from the urine. Faeces and urine were sub-sampled daily (10%) and composited over the whole period, prior to chemical analysis.

Nitrogen (N) retention was corrected for both endogenous urinary N (EUN) and metabolic faecal N (MFN) according to McDonald, Edwards & Greenhalgh (1988):

EUN (g) = 0.18g N/kg$^{0.75}$/day

MFN (g) = 5g N/kg DM intake

and

N-retention (gN/W$^{0.75}$/day) = $\{N_{in} - (N_{feaces} - MFN) - (N_{urine} - EUN)]/(W^{0.75})$/days.

Eight rumen fistulated Dohne merino wethers were fed *ad lib* to determine the dry matter (DM) and nitrogen (N) degradability of the two diets. This was done to indicate that while the ME-values of the two diets differed, there was little difference in the degradability of the diets and therefore the degradability did not influence the results of our investigation. Animals were treated and bags prepared as described by Lindberg (1985) and Madsen & Hvelplund (1994). Rumen degradability of DM and N were determined after a 48 hour incubation period.

The feed and faeces were analysed for DM, ash, CP, ether extract (EE) (AOAC, 1995), neutral detergent fibre (NDF) (Van Soest & Wine, 1967), acid detergent fibre (ADF) (Van Soest, 1963), calcium, phosphorus (Watson, 1994) and energy (AOAC, 1995). The urine samples were analysed for nitrogen and energy (AOAC, 1995). Gross energy (GE) was determined by adiabatic oxygen bomb calorimetry (CP500 calorimeter), while CP was determined by Kjeldahl procedure (Kjeltec system, 1002 Distilling unit).

Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1990). The following model was used to determine the presence of the three-way interaction:

$Y_{ijk} = \mu + S_i + D_j + A_k + SD_{ij} + SA_{ik} + DA_{jk} + SDA_{ijk} + e_{ijk}$

Y_{ijk} = Dependent variable of the $i^{'th}$ species of the $j^{'th}$ diet of the $k^{'th}$ slaughter age

μ = Overall mean

S_i = Species effect

D_j = Diet effect

A_k = Slaughter age effect

SD_{ij} = Species-diet interaction

SA_{ik} = Species-slaughter age interaction

DA_{jk} = Diet-slaughter age interaction

SDA_{ijk} = Species-diet-slaughter age interaction

e_{ijk} = Random error of measurement term

The differences between the diets, species and age were, where appropriate, tested separately by means of the null hypotheses (H_0), with H_0:$\mu=\mu_0$ and the alternate hypothesis (H_a) being H_a:$\mu\neq\mu_0$. This was done by means of contrast analyses and estimated least square means (± SE). Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$) for diet, species or slaughter age.

Table 1. Ingredients, chemical composition and effective rumen degradability of the two diets fed to BG kids and MM lambs

Item	Low Energy Diet	High Energy Diet
Ingredients[1]	%	%
Wheat Bran	1.50	0.00
Maize Meal	30.00	38.00
Sunflower Oilcake	1.64	4.46
Groundnut Oilcake	3.33	0.00
Limestone	0.07	0.58
Urea	0.70	0.59
Maize Germ [2]	0.00	9.31
Supermax Premix [3]	0.00	10.45
Vit/Min Premix [4]	0.21	0.21
Mono Calcium Phosphate	0.00	0.11
Salt	0.50	0.50
Citrus Ruminant Flavour	0.02	0.02
Ammonium Chloride	0.75	0.75
Taurotec[5]	0.03	0.03
NaOH Wheat Straw	21.26	15.00
Lucerne Hay	35.00	15.00
Molasses Cuber	5.00	5.00
Chemical composition [6]	**Content**	**Content**
Ash (%)	9.49	8.44
Crude Fat (%)	2.18	5.59
Crude Protein (%)	14.29	14.56
ADF (%)	24.74	17.78
NDF (%)	44.17	35.92
ME (MJ/kg) [7]	8.90	10.90
Calcium (%)	0.44	0.74
Phosphorus (%)	0.27	0.36
Effective rumen degradability [8]	%	%
Dry matter	78.36	82.74
Nitrogen	68.60	72.32

[1]On an air dry basis
[2]Supplied by Cape Oil (Berkleyroad, Box 16, Maitland)
[3]Rumen inert fat; supplied by Marine Oil (Division Tiger Food, Mainroad Didovalley, Simons Town)
[4]A standard mineral (macro and micro) and vitamin supplement formulated by Meadow Feed Mills (Westhovenstr, Box 262, Paarl) accoding to the NRC (1985).
[5]A growth promoter; supplied by Roche (Wycroftroad, Box 13167, Mowbray)
[6]Analysed values on a DM basis
[7]Based on the nutritive value of feeds according to laboratory determined values by Meadow Feed Mills
[8]After 48 h incubation in rumen

RESULTS AND DISCUSSION

As goats are selective feeders (Provenza, 1995), the diets in this investigation were pelleted. Santra, Karim, Mishra, Caturvedi & Prasad (1998) found that the predominantly browsing and highly selective feeding behaviour of goats are limiting factors in their utilisation in stall-feeding. These attributes can lead to variation in their feeding behaviour as well as influence their food selection under such conditions. A second reason for pelleting the diets, is that Casey & Webb (1995) and Webb, Bosman & Casey (1997) reported that the pelleting of high density diets may improve the composition and quality of ovine fat and thus both carcass and meat quality. Feeding pelleted diets also increases the ADG and decreases the feeding period as opposed to feeding diets in the loose form (Casey & Webb, 1995). One explanation given by the authors for this tendency is that wethers fed pelleted diets can not select specific feed components from the diets, and therefore achieve higher intakes and feed conversion ratios, compared to those fed diets in the loose form.

The growth parameters of the BG kids and MM lambs are presented in Table 2. As can be noted, there were no differences in initial body weights, within species, for either the diets or age at slaughter. Any differences in final body weight, within species, can therefore be attributed to main effects - diet and age at slaughter. The average daily gain (ADG) of the MM's on the LE-diet for 28 days (MMLE28) was lower ($P<0.01$) than those on the HE-diet (MMHE28) (0.236 vs. 0.330). However, there was no significant difference between the ADG of BG's on the high or low energy diets. Within a diet, the ADG of the MM's after 28 days were higher ($P<0.05$) than those of the BG's (HE: 0.330 vs. 0.217 and LE: 0.236 vs. 0.183 kg/day). These trends were also similar in the group of animals that were fed for 56 days, except that the MM's on the low energy diet (MMLE56) did not have a significantly higher ADG than either the BGLE56 or BGHE56.

In terms of feed conversion efficiency (FCE) the HEMM's were more efficient than those on the LE-diet (28 days: 5.56 vs. 8.73; 56 days: 6.47 vs. 9.40), regardless of the time spent in the feedlot. However, the BG's did not show significant differences in FCE between diets. In addition there was neither a significant difference in FCE between species within a diet, nor was there significant differences between animals of the same species, on the same diet for different periods of time in the feedlot.

McGregor (1985) as cited by Warmington & Kirton (1990) observed slower growth rates and greater fat deposition in goats fed high energy diets compared to pasture-fed contemporaries. Malik, Razzaque, Abbas, Alokhozam & Sahni (1996) found that although lambs fed a high (12.7 MJ ME/kg DM) energy diet ate less than the lambs fed a low (11 MJ ME/kg DM) or medium (11.9 MJ ME/kg DM) metabolisable energy diet, the former were the most efficient in feed conversion efficiency (5.59 vs. 6.43 and 6.43). The same tendency was found with the lambs in the present investigation.

Table 2. Growth parameters, average feed intake and conversion efficiency of the Mutton merino lambs and Boer goat kids receiving either a LE or HE diet (mean ± SE)

	BGLE28[1)] (n=16)	BGHE28[2)] (n=15)	MMLE28[3)] (n=16)	MMHE28[4)] (n=16)	BGLE56[1)] (n=8)	BGHE56[2)] (n=7)	MMLE56[3)] (n=8)	MMHE56[4)] (n=8)
Initial body weight (kg)	25.75[a] ± 0.793	26.73[a] ± 0.819	32.16[b] ± 0.793	32.97[b] ± 0.793	25.75[a] ± 1.121	26.71[a] ± 1.198	32.13[b] ± 1.121	33.31[b] ± 1.121
Final body weight (kg)	30.88[b] ± 1.013	32.80[ab] ± 1.046	38.76[cf] ± 1.013	42.2o[d] ± 1.013	34.27[ab] ± 1.432	35.79[ac] ± 1.531	43.51[d] ± 1.432	49.05[e] ± 1.432
Body weight gain (kg)	5.13[a] ± 0.497	6.07[ad] ± 0.514	6.61[d] ± 0.497	9.23[b] ± 0.497	8.52[b] ± 0.704	9.08[b] ± 0.752	11.39[e] ± 0.704	15.74[c] ± 0.704
Cumulative feed intake (kg)	36.30[a] ± 2.388	35.48[a] ± 2.466	48.89[d] ± 2.388	50.57[d] ± 2.388	75.35[c] ± 3.377	60.16[b] ± 3.610	106.00[e] ± 3.377	99.84[e] ± 3.377
ADG (kg/day)	0.183[ac] ± 0.016	0.217[ae] ± 0.016	0.236[e] ± 0.015	0.330[d] ± 0.015	0.152[c] ± 0.021	0.162[bc] ± 0.023	0.203[abc] ± 0.021	0.281[de] ± 0.021
FCE (kg feed/kg weight gain)	7.65[bc] ± 0.684	6.37[ab] ± 0.707	8.73[cd] ± 0.684	5.56[a] ± 0.684	9.09[cd] ± 0.967	6.62[abc] ± 1.034	9.40[d] ± 0.967	6.47[ab] ± 0.967
Cold carcass weight[5)] (kg)	12.72[b] ± 0.777	15.22[a] ± 0.777	16.28[a] ± 0.777	19.42[c] ± 0.777	15.25[a] ± 0.777	17.13[a] ± 0.831	19.85[c] ± 0.777	24.58[d] ± 0.777
Dressing percentage[5)] (%)	40.96[c] ± 0.647	45.38[adf] ± 0.647	42.22[c] ± 0.647	47.02[df] ± 0.647	44.53[af] ± 0.647	47.85[bd] ± 0.691	45.61[f] ± 0.647	50.14[e] ± 0.647
Dressing percentage[6)] (%)	52.24[b] ± 0.739	55.39[a] ± 0.790	52.91[b] ± 0.739	56.48[ac] ± 0.739	57.69[cd] ± 0.739	56.85[ace] ± 0.739	58.76[de] ± 0.739	59.37[d] ± 0.739

[1)]BGLE28/56: Low Energy diet, fed to Boer goats for 28/56 days

[2)]BGHE28/56: High Energy diet, fed to Boer goats for 28/56 days

[3)]MMLE28/56: Low Energy diet, fed to Mutton merinos for 28/56 days

[4)]MMHE28/56: High Energy diet, fed to Mutton merinos for 28/56 days

[5)]n=8 for all treatment groups (carcass with kidneys and kidney fat intact), as a % of live weight

[6)]n=8 for all treatment groups (carcass without kidneys and kidney fat), as a % of empty body weight

[a,b,c] Means in the same row with different superscripts differ (P<0.05)

In terms of the cold carcass weight (Table 2) the animals on the HE-diet that were slaughtered after 28 days, had a higher (P<0.05) weight than the animals on the LE diet for both species. Within diets the MM's had a higher cold carcass weight than the BG's. The MMHE56 also had a higher weight than the MMLE56, BGHE56 and BGLE56, but there were no significant difference between the cold carcass weight of the BGHE56 and BGLE56. The 28-day group of animals showed no significant difference for dressing percentage (as a percentage of live weight) within a diet. The MMHE56 had a significantly higher dressing percentage (50.14%) than the MMLE56, BGLE56 and BGHE56 (45.61, 44.53 and 47.85% respectively). In both the 28- and 56-day groups the animals on both the HE-diet had higher (P<0.01) dressing percentages than their contemporaries on the LE-diet. However, once the dressing percentage was calculated as a percentage of EBW, there was neither a difference between BGLE56 and BGHE56, nor between MMLE56 and MMHE56. These results illustrate that the differences that occurred when dressing percentage was calculated as a percentage of live weight, was due to a higher level of gut fill on the part of the LE-animal. According to Warmington & Kirton (1990), dressing percentages of goats vary between 35 and 53%. While kids and lambs are consuming milk only, they are essentially monogastric and will have the highest dressing percentage, because of the low level of gut full. As kids start eating fibrous material, the rumen will develop and gut fill will increase – reducing dressing percentage. As the goat or sheep approaches maturity and fat is accumulated in the carcass, the dressing percentage will again increase (Warmington & Kirton, 1990). Naude & Hofmeyr (1981) reported dressing percentages of 49 to 52 % in concentrate-fed male Boer goat kids from 23 to 42 kg live weight. These were greater than or similar to dressing percentages of Merino, MM and Dorper sheep in the same trial. Warmington & Kirton (1990), however, concluded that dressing percentages of different goat breeds are similar and may be slightly lower than those for sheep (which was the case in the present study), partly because goats are leaner animals.

Table 3 shows the apparent digestibilities of the different components of the two diets. DM digestibility showed a species x diet interaction, since the BG seemed to digest the LE-diet to a greater extend than the HE-diet (85.52 vs. 74.70%), but the MMHE (75.65%) digested their diet more efficiently than the MMLE (68.64%).

Both the BGLE and BGHE digested the CP better (P<0.05) than the MMLE. Within a diet, no significant difference could be found between BG's and MM's in crude fat (CF) digestion, although the HE-diet's CF was digested more efficiently (P<0.01).

There was neither a difference in ADF nor in NDF digestibility between or within species and diets. Energy digestibility also showed a species x diet interaction, since the BG seemed to digest energy more efficiently on the LE-diet than on the HE-diet (80.81 vs. 73.10%). The opposite was evident with the MM's. It is also important to note that the BGLE digested the

DM, CP and energy more efficiently (P<0.05) than the MMLE, while there was no apparent difference (P>0.05) in the digestibility of any of the components between the BGHE and MMHE. These findings agree with that of Aregheore (1996) who indicated that sheep and goats have a similar digestive efficiency on a good-quality feed, whereas goats perform better than sheep on a low-grade roughage. According to Aregheore (1996) and Gihad , El-Bedawy & Mehrez (1980) the better nutrient utilisation in goats than sheep on low-grade feeds could be ascribed to their efficient fibre digestion which was not evident in this study. Morales *et al.* (2000) found that goats, adequately supplemented with small amounts of essential nutrients, performed equally well on a lower digestible feed as their contemporaries did on a higher one. Al-Nakib, Al-Shukaily, Al-Hanai & Al-Nabhani (1996) concluded that sheep are more responsive than goats to a better environment and are therefore more efficient in utilising a high quality diet.

Table 3. Apparent digestibility of the diets fed to Boer goat kids and Mutton merino lambs (mean ± SE)

Chemical component (%)	BGLE[1)] (n=6)	BGHE[2)] (n=6)	MMLE[3)] (n=6)	MMHE[4)] (n=6)
DM	$82.52^{a} \pm 1.488$	$74.70^{b} \pm 1.488$	$68.64^{c} \pm 1.488$	$75.65^{b} \pm 1.488$
Ash	$65.66^{a} \pm 1.856$	$66.23^{a} \pm 1.856$	$67.8^{a} \pm 1.856$	$69.54^{a} \pm 1.856$
Crude Protein	$75.07^{a} \pm 1.491$	$76.81^{a} \pm 1.491$	$70.16^{b} \pm 1.491$	$74.32^{ab} \pm 1.491$
Crude Fat	$69.84^{a} \pm 1.701$	$88.23^{b} \pm 1.701$	$69.97^{a} \pm 1.701$	$87.56^{b} \pm 1.701$
ADF	54.46 ± 2.752	49.87 ± 2.752	50.91 ± 2.752	52.66 ± 2.752
NDF	62.14 ± 2.196	61.07 ± 2.196	58.68 ± 2.196	62.46 ± 2.196
Energy	$80.81^{a} \pm 1.661$	$73.10^{b} \pm 1.661$	$65.08^{c} \pm 1.661$	$74.13^{b} \pm 1.661$

[1)]BGLE: Low Energy diet, fed to Boer goats
[2)]BGHE: High Energy diet, fed to Boer goats
[3)]MMLE: Low Energy diet, fed to Mutton merinos
[4)]MMHE: High Energy diet, fed to Mutton merinos
[a,b,c] Means in the same row with different superscripts differ (P<0.05)

Energy intake (MJ/day), excretion (MJ/day), retention (MJ/day) and metabolisable energy content (ME, MJ/kg) of the diets are presented in Table 4. Although there are no significant difference between the energy retention of the BGHE and MMHE (62.78 vs. 63.73% of energy intake), there is a significant difference between the energy retention of the BGLE (69.39%) and MMLE (54.85%). The result of this energy retention, is that although there is a difference

(P<0.01) between the ME of the LE-diet and HE-diet for the MM's, there is no significant difference in ME for the BG's. The HE-diet had the same ME (P>0.05) for both the MM's and the BG's, but the LE-diet had a significantly higher (P<0.01) ME for the BG's than the MM's. The ME-values obtained in the digestibility study for the MM are approximately the same as those calculated from the nutritive values of the feeds (Table 1) (LE: 8.66 vs. 8.90 and HE: 10.63 vs. 10.90 MJ/kg DM). This was also true for the HE-diet when given to the BG's (10.51

Table 4. Energy metabolism of Boer goat kids and Mutton merino lambs fed the high and low energy diets (mean ± SE)

	BGLE[1)] (n=6)	BGHE[2)] (n=6)	MMLE[3)] (n=6)	MMHE[4)] (n=6)
DM intake (g/day)	1124.99 ^{a} ± 102.040	910.44 ^{a} ± 102.040	1504.21 ^{a} ± 102.040	1171.13 ^{a} ± 102.040
Gross energy (MJ/kg)	15.973	16.759	15.973	16.759
Energy intake (MJ/day)	17.97 ^{a} ± 1.650	15.26 ^{a} ± 1.650	24.03 ^{b} ± 1.650	19.63 ^{a} ± 1.650
Faecal energy (MJ/day)	3.54 ^{a} ± 0.471	4.11 ^{ab} ± 0.471	8.26 ^{c} ± 0.471	5.03 ^{b} ± 0.471
Urinary energy (MJ/day)	0.528 ^{b} ± 0.3836	0.353 ^{a} ± 0.3836	0.671 ^{c} ± 0.3836	0.517 ^{b} ± 0.3836
Methane gas production (MJ/day)[5)]	1.44 ^{a} ± 0.132	1.22 ^{a} ± 0.132	1.92 ^{b} ± 0.132	1.57 ^{ab} ± 0.132
Total energy excreted (MJ/day)	5.50 ^{a} ± 0.578	5.68 ^{a} ± 0.578	10.85 ^{b} ± 0.578	7.11 ^{a} ± 0.578
Faecal energy (% of energy intake)	19.19 ^{b} ± 1.661	26.9 ^{a} ± 1.661	34.92 ^{c} ± 1.661	25.87 ^{a} ± 1.661
Urinary energy (% of energy intake)	3.01 ^{a} ± 0.258	2.39 ^{a} ± 0.258	2.87 ^{a} ± 0.258	2.72 ^{a} ± 0.258
Total energy excreted (% of energy intake)	30.20 ^{b} ± 1.686	37.29 ^{a} ± 1.686	45.79 ^{c} ± 1.686	36.59 ^{a} ± 1.686
Energy retention (MJ/day)	12.47 ^{a} ± 1.228	9.58 ^{a} ± 1.228	13.17 ^{a} ± 1.228	12.51 ^{a} ± 1.228
Energy retention (% of energy intake)	69.80 ^{b} ± 1.686	62.71 ^{a} ± 1.686	54.21 ^{c} ± 1.686	63.41 ^{a} ± 1.686
ME (MJ/kg)	11.15 ^{a} ± 0.273	10.51 ^{a} ± 0.273	8.66 ^{b} ± 0.273	10.63 ^{a} ± 0.273

[1)]BGLE: Low Energy diet, fed to Boer goats
[2)]BGHE: High Energy diet, fed to Boer goats
[3)]MMLE: Low Energy diet, fed to Mutton merinos
[4)]MMHE: High Energy diet, fed to Mutton merinos
[5)]Calculated as 8% of Energy intake (McDonald *et al.*, 1988)
^{a,b,c} Means in the same row with different superscripts differ (P<0.05)

vs.10.90 MJ/kg) but not for the LE-diet (11.15 vs. 8.90 MJ/kg). These findings agree partly with the AFRC (1988) who stated that conventional feeds (i.e. excluding low-quality roughage fed without N supplements) are likely to have the same digestible energy (DE) value, and presumably metabolisable energy (ME) value for both sheep and goats. Therefore it seems as if the calculated ME values of diets formulated for sheep, can not under all circumstances be used as an indicator of the ME values for goats.

Nitrogen metabolism and retention of the BG kids and MM lambs on the two diets can be seen in Table 5. Only faecal nitrogen showed a species x diet interaction. Nitrogen intake (g/day) as well as urinary, faecal and total N excretion (g/day) were the highest ($P<0.05$) for the MM's on the LE-diet. When N retention ($gN/kgW^{0.75}/day$) was corrected for both endogenous urine N and metabolic N in the feaces, there was no significant difference in nitrogen retention. Therefore it can be concluded that neither diet nor species influenced nitrogen retention.

Table 5. Nitrogen metabolism in Boer goat kids and Mutton merino lambs fed high and low energy diets (mean ± SE)

	BGLE[1)] (n=6)	BGHE[2)] (n=6)	MMLE[3)] (n=6)	MMHE[4)] (n=6)
DM intake (g/day)	1124.99 ^{a} ± 102.040	910.44 ^{a} ± 102.040	1504.21 ^{b} ± 102.040	1171.13 ^{a} ± 102.040
Nitrogen intake (g/day)	25.75 ^{a} ± 2.346	21.22 ^{a} ± 2.346	34.43 ^{b} ± 2.346	27.29 ^{a} ± 2.346
Faecal nitrogen (g/day)	3.75 ^{a} ± 0.550	4.66 ^{a} ± 0.550	9.50 ^{c} ± 0.550	6.43 ^{b} ± 0.550
Urinary nitrogen (g/day)	13.329 ^{b} ± 1.002^{b}	9.82 ^{a} ± 1.002	18.51 ^{c} ± 1.002	13.87 ^{b} ± 1.002
Total nitrogen excreted (g/day)	17.08 ^{ab} ± 1.301	14.48 ^{a} ± 1.301	28.01 ^{c} ± 1.301	20.30 ^{b} ± 1.301
Faecal nitrogen (% of nitrogen intake)	14.27 ^{b} ± 1.303	21.85 ^{a} ± 1.303	27.97 ^{c} ± 1.303	23.72 ^{a} ± 1.303
Urinary nitrogen (% of nitrogen intake)	53.1 ^{a} ± 4.448	47.42 ^{a} ± 4.448	55.29 ^{a} ± 4.448	52.07 ^{a} ± 4.448
Total nitrogen excreted (% of nitrogen intake)	67.37 ^{a} ± 4.879	69.28 ^{ab} ± 4.879	83.27 ^{b} ± 4.879	75.79 ^{ab} ± 4.879
Nitrogen retention ($gN/kgW^{0.75}/day$)	1.35 ± 0.153	1.26 ± 0.153	1.49 ± 0.153	1.21 ± 0.153

[1)]BGLE: Low Energy diet, fed to Boer goats
[2)]BGHE: High Energy diet, fed to Boer goats
[3)]MMLE: Low Energy diet, fed to Mutton merinos
[4)]MMHE: High Energy diet, fed to Mutton merinos
[a,b,c] Means in the same row with different superscripts differ ($P<0.05$)

CONCLUSIONS

The MM's in this investigation had a significantly higher ADG than the BG's. In terms of FCE the MMHE was more efficient ($P<0.05$) than the MMLE, but the BG's did not show significant differences in FCE between diets. In addition there was no difference in FCE between the MM's and BG's on the same diet. The fact that the BG's had lower ADG's, but not lower FCE's, suggests that they may also be suitable for feedlot finishing when the overhead costs are minimal.

The BGLE digested DM, CP and energy more efficiently ($P<0.05$) than the MMLE, while there was no apparent difference in the digestibility of any of the components between BGHE and MMHE. BG's on the LE-diet also had a significantly higher energy retention than the MMLE, although this was not evident with animals on the HE-diet. These two findings support the hypothesis that goats perform better on a lower quality feed than sheep, but that sheep and goats have a similar digestive efficiency on a good-quality feed.

The BGLE digested the DM of their diet more efficiently ($P<0.05$) and had a higher energy retention (% of energy intake) than the BGHE. This may explain why there was no significant difference in ADG and FCE between the BGHE and BGLE. The result is that the two diets had the same ME-value for the goats, which confirms that goats perform equally well on a lower quality feed as their contemporaries on a higher one (Morales *et al.*, 2000).

The fact that the LE-diet had a significantly higher ME-value for the BG's than for the MM's, indicate that calculated ME-values of diets formulated for sheep can not under all circumstances be used as an indicator of the ME-values for goats.

Boer goats may be finished on a diet with a lower ME value than which is usually formulated for sheep, without a reduction in performance. This may render a direct economic advantage for BG feedlot finishing.

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WATER INTAKE OF BOER GOATS AND SA MUTTON MERINOS RECEIVING EITHER A LOW OR HIGH ENERGY FEEDLOT DIET

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ABSTRACT

Individual water consumption and intake per unit body weight gain of 16 castrated Boer goat kids and 16 South African Mutton merino wether lambs were investigated. Two pelleted diets (fed to 8 animals/species) with either a low (8.9 MJ/kg DM) or a high (10.9 MJ/kg DM) metabolisable energy level were fed individually, *ad lib* for 56 days. The Boer goat had a 49 % lower (P<0.01) water intake per kg weight gain than the Mutton merino on both the high and low energy diets. Both species had a lower (P<0.01) intake on the high than on the low energy diet. Furthermore, the Boer goat had a daily water intake of only 171 ml/kg$^{0.75}$ compared to the 302 ml/kg$^{0.75}$ of the Mutton merino.

Keywords: water intake, diet energy content, feedlot.

INTRODUCTION

Limited water availability is a major factor influencing the productivity of ruminants in desert and tropical regions (Shkolnik & Silanikove, 1981). A hot environment reduces the voluntary food intake and increases the feed utilization of ruminants (Silanikove, 1992). As dry matter and water intake are linearly related to each other (MacFarlane & Howard, 1972; Silanikove, 1987a), water restriction or dehydration reduces voluntary feed intake (Balch, Balch, Johnson & Turner, 1953; Silanikove, 1985). Breeds of ruminants which are well adapted to a desert environment demonstrate a greater capability to ameliorate the stressful effects induced by water deprivation (Maltz *et al.*, 1984; Silanikove, 2000) and therefore maintain higher feed intake and productivity, than non-desert breeds. The physiological mechanism that enables desert goats to cope with severe water deprivation is consistent with an unusual ability to withstand dehydration, and to minimize water losses via urine and faeces (Silanikove, 2000). Goats living in harsh environments represent a climax in the capacity of domestic ruminants to adjust to such areas. Factors influencing this ability includes their small body size, low metabolic requirements, ability to reduce metabolism, digestive efficiency in relation to feeding strategies, efficiency of utilisation of high fibre forage, efficient usage of water, as well as their ability to economise the nitrogen requirements via urea recycling and nitrogen conservation (Silanikove, 2000). Since desert-adapted ruminants are more likely to utilize their water reservoir more efficiently, it enables them to maintain their appetite and production potential more effectively under heat stress conditions (Degen & Shkolnik, 1978; Silanikove, 1987b; Silanikove, 1994). Therefore, where water is scarce, those animals capable of using it as efficiently as possible will maximize production. The aim of this investigation was to determine the average daily water intake per unit dry matter intake and per unit body weight gain for Boer goats (BG) and South African Mutton merinos (MM) receiving either a high or low energy feedlot diet.

MATERIALS AND METHODS

Sixteen BG wether kids and 16 MM wether lambs of a similar age were used for this study. The average initial body weight of the kids and lambs were 26.23 ± 3.86 kg and 32.72 ± 2.13 kg, respectively (average ± SE). The animals were randomly allocated to two treatment groups of eight animals per species and housed individually in an enclosed but adequately ventilated shed with a slated floor. The study was conducted between October and December 1999 on the experimental farm, Welgevallen, of the University of Stellenbosch, South Africa. Two pelleted diets were formulated according to the NRC (1985) recommendations for lambs, on an isonitrogenous basis (14.4% crude protein (CP) on a DM basis) to contain either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) calculated metabolisable energy level. The animals received the diets *ad lib* for 56 days. Lambs and kids were fed twice daily, at 07h00 and 16h00. The animals were given 8 l of water each morning at 07h00. Weekly water intake, corrected for evaporation losses by measuring losses from a trough similar to those provided for the animals, was monitored. The animals were weighed weekly. Feed intake, feed conversion efficiency (kg feed/kg weight gain) (FCE), water intake per unit body weight gain (l/kg) and water intake per unit feed intake (l/kg) were calculated for each animal.

Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1990). The differences between the diets, species and age were, where appropriate, tested separately by means of the null hypotheses (H_0), with H_0:$\mu=\mu_0$ and the alternate hypothesis (H_a) being H_a:$\mu\neq\mu_0$. This was done by means of contrast analyses and estimated least square means (± SE). Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$) for diet, species or age.

RESULTS AND DISCUSSION

Body weight, weight gain, means for cumulative feed and water intakes, FCE and water intake per unit dry matter intake and water intake per unit body weight gain between BG's and MM's are presented in Table 1. Cumulative feed intakes on the LE and HE diets were respectively, 41 and 66% higher (P<0.05) in the MM's than in the BG's. In terms of FCE (kg feed/kg body weight gain), there was no significant differences within diets, but the FCE of MMHE (6.5) and BGHE (6.6) were respectively, 45 and 38% lower (P<0.05) than those of MMLE (9.4) and BGLE (9.1). However, when food intake is presented as energy intake per unit body weight gain (MJ/kg), the BGHE are not more efficient than the BGLE (79.88 vs. 80.89). In contrast, MM's are more efficient on the HE-diet than on the low energy diet (70.53 vs. 83.67). This may be due to the fact that, unlike the BG, the MM are bred for meat production and can utilize the extra energy more efficiently.

Cumulative water intake differed (P<0.05) between the two breeds, with that of the MM's 158 and 101% higher than the BG's on the high and low energy diets respectively. The BGHE's cumulative water intake was also 33% lower (P<0.05) than that of the BGHE's. On calculating the water intake per energy intake (l/MJ) the BG's once again had a lower intake of water than the MM's and both species had a lower intake on the HE-diet than on the LE-diet.

Although FCE did not differ between species within diets (HE or LE), the water intake per unit body weight gain differed (P<0.05). MM consumed 49% more water (P<0.01) per unit body weight gain than the BG on both the HE and LE diets. Both the MM and BG had a 43% lower intake per unit weight gain (l/kg) on the HE than on the LE diets (P<0.05). Individual water intake per day (l/d) for the MMLE varied from 4.40 to 5.44 l/d, and in the MMHE it varied between 3.69 and 5.48 l/d. Individual water intake in the BG's was lower than those of the MM's (BGLE: 1.99 to 3.20 l/d; BGHE: 1.11 to 2.21 l/d).

The amount of water consumed by the BG's (2.3 ± 0.4 l) was similar to that of Blackhead Persian lambs (2.3 ± 0.28 l), higher than that of Pedi goats (1.4 ± 0.4 l), but lower than that of Dorper (4.8 ± 0.58 l) (Schoeman & Visser, 1995; Qinisa & Boomker, 1998) and MM lambs (4.8 ± 0.5 l). When the volume of water consumed was compared on a per kilogram feed intake basis (l/kg feed intake), Pedi goats (1.6 ± 0.2) consumed less water than both the BG's (1.8 ± 0.2), Blackhead Persian (1.8 ± 0.2), Dorper (2.6 ± 0.2) and MM (2.6 ± 0.3). On calculating the daily water intake per metabolic weight (ml/kg$^{0.75}$), Pedi goats had a significantly lower intake (124.9 ± 35.7) (P<0.014, Comparison of Means) than the BG's (171.0 ± 26.0), the Blackhead Persian (163.4 ±19.6), Dorper (246.1 ± 29.8) and MM (301.5 ± 28.9).

Water and food intake are highly correlated (Clarke & Quin, 1949; MacFarlane & Howard, 1972; More, Howard & Siebert, 1983; Hamilton & Webster, 1987; Silanikove, 1989). Similar water intake to food intake relationships were observed in this investigation. MM lamb's and BG kids show similar linear responses but the HE and LE lambs had a higher (P<0.05) water intake per unit feed intake (Table 1) than the HE and LE kids. Accordingly, it is feasible to assume that the reduced water intake in the BG's was not due to a decreased feed intake. Therefore the BG, like the Blackhead Persian (Schoeman & Visser, 1995), is probably capable

Table 1. Initial and final weight, body weight gain, cumulative feed and water intake, feed and water efficiency and water consumption in Boer goat kids and Mutton merino lambs (mean ± SE) under feedlot conditions

	BGLE[1)] (n=8)	BGHE[2)] (n=7)	MMLE[1)] (n=8)	MMHE[2)] (n=8)
Initial body weight (kg)	25.8^a ± 1.11	26.7^a ± 1.19	32.1^b ± 1.11	33.3^b ± 1.11
Final body weight (kg)	34.3^a ± 1.40	35.8^a ± 1.50	43.5^b ± 1.40	49.1^c ± 1.40
Body weight gain (kg)	8.5^a ± 0.77	9.1^{ab} ± 0.83	11.4^b ± 0.77	15.7^c ± 0.77
Cumulative feed intake (kg)	75.4^a ± 4.52	60.2^b ± 4.83	106.0^c ± 4.52	99.8^c ± 4.52
Feed conversion efficiency (kg feed/kg weight gain)	9.1^a ± 0.47	6.6^b ± 0.50	9.4^a ± 0.47	6.5^b ± 0.47
Cumulative water intake (l)	136.7^a ± 8.32	102.4^b ± 8.90	275.4^c ± 8.32	264.5^c ± 8.32
Water intake per unit body weight gain (l/kg)	16.4^a ± 0.83	11.48^b ± 0.88	24.4^c ± 0.83	17.1^a ± 0.83
Water consumption per unit feed intake (l/kg)	1.8^a ± 0.08	1.7^a ± 0.09	2.6^b ± 0.08	2.6^b ± 0.08
Energy intake per kg body weight gain (MJ/kg)	80.89^{ab} ± 4.347	79.88^{ab} ± 4.647	83.67^b ± 4.347	70.53^a ± 4.347
Water intake per energy intake (l/MJ)	0.205^a ± 0.0084	0.157^b ± 0.0090	0.296^c ± 0.0084	0.242^d ± 0.0084

[1)]MM/BGLE: Low-energy diet, fed to South African Mutton merinos/Boer goats
[2)]MM/BGHE: High-energy diet, fed to South African Mutton merinos/Boer goats
[a,b,c] Means in the same row with different superscripts differ statistically ($P<0.05$)

of budgeting its water requirements more economically than the MM. According to Fairall & Klein (1984) and Silanikove (1989) water turnover is related to metabolic rate and the different water requirements of BG's and MM's can therefore be explained in evolutionary terms through the different adaptation strategies of the two species. Both BG and Blackhead Persian are well adapted to arid conditions. The BG has an energy conserving lifestyle, being a bulk and roughage feeder (high fibre, low crude protein forage), it probably needs less water for metabolism and nitrogen excretion. On the other hand, the MM has been selected and farmed on higher quality pastures (high crude protein, low fibre forage) and therefore probably needs a higher water turnover for the excretion of nitrogen in the urine as has been demonstrated in the Blesbok and Impala (Fairall & Klein, 1984).

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BODY COMPONENTS AND COMMERCIAL YIELD OF BOER GOAT KIDS AND SA MUTTON MERINO LAMBS RECEIVING EITHER A LOW OR A HIGH ENERGY FEEDLOT DIET

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ABSTRACT

Offal components, carcass measurements and commercial cuts of 32 Boer goat (BG) kids and 32 South African Mutton merino (MM) lambs were investigated. Two pelleted diets (fed to 16 animal/species) with either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) metabolisable energy level were fed, *ad lib,* for either 28 or 56 days. Thereafter the animals were slaughtered and the carcasses dissected into South African commercial cuts. The weight of the liver, empty stomach, head and feet (as a percentage of empty body weight) were higher in goats than in sheep. The MM's had significantly heavier skins, probably due to wool growth. Both kidney fat and gastro-intestinal (GIT) fat increased with age. The animals slaughtered after 56 days in the feedlot had significantly longer and deeper carcasses than their contemporaries slaughtered after 28 days. Within a diet and slaughter age, the MM had significantly broader and deeper carcasses than the BG's. BG's had significantly less weight per unit carcass length, and thus more slender carcasses than MM's. MM's also had heavier carcasses (LE: 19.87 vs. 15.28 kg; HE: 24.01 vs. 17.05 kg), and proportionally heavier ribs and buttocks than BG's and therefore one can expect higher prices for sheep carcasses than for that of goats. Since diet had no significant influence on the carcass weight distribution of the goats, BG's can be finished on a LE-diet in the feedlot. This may decrease the feed cost significantly.

Keywords: offal components, carcass measurements, commercial cuts, diet energy content.

INTRODUCTION

One of the reasons why meat supply does not meet human demand is that man has concentrated on utilising a relatively few animal species as a source of meat (Gaili & Ali, 1985). Exploitation of unconventional livestock such as goats is advocated as a means of increasing global meat production and consumption (Babiker, El Khider & Shafie, 1990). Goat populations in developing countries represent 94% of the world total. Despite their numerical importance goat meat is little consumed and commands a low price compared with beef and mutton. In 2000 Africa had 22.8% and 29.1% of the total world's sheep and goat populations, respectively (FAO, 2001). Within the African society, sheep and goats comprise a greater proportion of the total wealth of poor families (Peacock, 1996) and are the primary source for meat and meat products. These flocks are raised under a wide variety of ecological zones and are able to survive and produce in harsh environmental conditions that are difficult for cattle to survive in (El Khidir, Babiker & Shafie, 1998). Although South Africa possesses large numbers of domestic ruminants, red meat consumption has been limited mainly to sheep and cattle. Goats are used to a lesser extent. This is partly attributed to a general belief that goat meat is inferior to mutton and beef. El Khidir *et al.* (1998) suggested that feedlotting of goats can be recommended when feed ingredients are cheap. If goat meat is recognised as a healthy food commodity, due to its lean nature, and the consumer is willing to pay competitive prices for it, then feedlotting of goats can be advocated. From July 1998 to June 1999, 4.6 million sheep, lambs and goats were slaughtered in South Africa. The total mutton production in South Africa was 104 400 t, while the mutton import was 49 800 t. The total consumption of mutton and goat was 153 000 t, while the *per capita* consumption was 3.6 kg (Agricultural Statistics, 2000). According to USAID (1998) 30 579 goats were slaughtered in abattoirs in 1997.

Carcasses of meat animals are composed primarily of varying proportions of muscle, fat and bone. In developed countries where overabundance of calories is a major nutritional problem, muscle is the most important carcass tissue. Certain muscles, such as those of the hindleg and loin, contribute to the higher-priced cuts of the carcass, because there is less associated fat and connective tissue (Thonney, Taylor, Murray & McClelland, 1987). For this reason differences in species, degree of maturity and the distribution of muscles are commercially important.

The potential of the Boer goat (BG) as a meat-producing animal has been recognised by early researchers such as Owen & Norman (1977) and Casey (1983). However, little is known about the performance of goats under intensive conditions. Oman, Waldron, Griffin & Savell (1999) found that feedlot goats, in comparison to range goats, had heavier live and carcass weights and carcasses that yielded more dissectible fat and lean tissue and less bone, as a percentage of carcass weight.

The South African Mutton merino (MM) was selected as a standard to compare with the BG for this investigation. The MM is a dual-purpose breed, developed to produce a slaughter lamb at an early age. It has a high fertility, good conformation, good feed conversion ratio and adaptability and is therefore popular in feedlot production systems.

Due to species and environmental differences, the weaning age and weight of BG's differ from that of MM's in this investigation. At the start of this investigation, the BG's were 135 days and the MM's 90 days of age, which represents the actual weaning age of the animals as well as

the age at which they would enter a commercial feedlot. The economy of a feedlot requires that animals be slaughtered at a targeted weight or after a certain amount of days in the feedlot. In this investigation, this duration was either 28 or 56 days.
Therefore, this investigation was conducted to determine the influence of dietary energy levels and duration in the feedlot on the distribution of body and carcass weight of the BG kid in comparison to the MM lamb.

MATERIALS AND METHODS

Thirty-two BG kids and 32 MM lambs were used for this investigation. All the animals were castrated and weaned before entering the feedlot. The average initial body weight of the kids and lambs were 26.23 ± 3.86 kg and 32.72 ± 2.13 kg, respectively. The animals were randomly allocated to four treatment groups of eight animals per species and housed individually in an enclosed but adequately ventilated shed with a slatted floor. The individual pens were built of a material that allowed adjacent animals so see and interact with each other. The study was conducted between October and December 1999 on the experimental farm of the University of Stellenbosch, South Africa. Two pelleted diets were formulated according to the NRC (1985) recommendations for lambs, on an isonitrogenous basis (14.4% crude protein (CP) on a DM basis) to contain either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) calculated metabolisable energy level. The animals received the diets and water *ad lib*. The animals were weighed weekly. The feedlot performance of this trial has been reported (Sheridan, Ferreira & Hoffman, 2001a).
After 28 days, 16 BG's and 16 MM's were slaughtered, while the rest of the animals continued in the trial until day 56, when they were slaughtered. When slaughtered, the animals were first stunned electronically (200V for 10s). After exsanguination the carcasses were hung to bleed. No electrical stimulation of the carcasses was applied.
The carcasses were eviscerated using standard procedures. All internal organs, as well as GIT (gastro-intestinal tract) fat were weighed individually. The stomachs (rumen, reticulum, omasum and abomasum combined) and intestines (small intestine, large intestine and caecum combined) were emptied, washed and weighed. The weight of the organs are expressed as a percentage of empty body weight (EBW), in order to prevent the effect of rumen fill differences. The weight of the head, feet and skin were also recorded. "Edible offal" was calculated as the sum of the heart, liver, lungs & trachea, spleen, stomach, intestines, kidneys, kidney fat and GIT-fat as a percentage of EBW. "Non-edible offal" was defined as the sum of the skin, head and feet as a percentage of EBW.
The carcasses were then hung in a cooler (4°C) for 24 hours, before the maximum length (break joint to break joint), maximum breadth (side to side) and maximum depth (back to chest) of each carcass were measured. The carcasses of the 56-day animals were sawn

medially through the vertebrae. Both sides of each carcass were jointed into 7 individual cuts, following the South African Meat Board's chart for retail mutton cuts (Hoffman, 2000). These cuts consisted of the neck, breast, thick rib, rib, loin, flank and buttock and were all weighed separately.

Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1990). The following model was used to determine the presence of the three-way interaction:

$Y_{ijk} = \mu + S_i + D_j + A_k + SD_{ij} + SA_{ik} + DA_{jk} + SDA_{ijk} + e_{ijk}$

Y_{ijk} = Dependent variable of the i'th species of the j'th diet of the k'th slaughter age

μ = Overall mean

S_i = Species effect

D_j = Diet effect

A_k = Slaughter age effect

SD_{ij} = Species-diet interaction

SA_{ik} = Species-slaughter age interaction

DA_{jk} = Diet-slaughter age interaction

SDA_{ijk} = Species-diet-slaughter age interaction

e_{ijk} = Random error of measurement term

The differences between the diets, species and slaughter ages were, where appropriate, tested separately by means of the null hypotheses (H_0), with $H_0{:}\mu=\mu_0$ and the alternate hypothesis (H_a) being $H_a{:}\mu\neq\mu_0$. This was done by means of contrast analyses and estimated least square means (± SE). Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$) for diet, species or age.

RESULTS AND DISCUSSION

Unless otherwise indicated, no significant interactions between diet, species and slaughter age were present. According to McCulloch & Talbot (1965), even with similar animals of the same species, variations in the weight of the stomach content can amount to 10% of live weight. Hence, Table 1 presents the carcass weight as well as the proportional weight distribution of the organs, and tissue as a percentage of EBW of the BG kids and MM lambs.

Within a species, the proportional weight of the lungs & trachea, spleen, empty intestines and edible offal were not influenced by diet. The same trend was evident in the proportional weight of the heart, liver, skin and non-edible offal.

On the LE-diet sheep hearts had heavier proportional weights than that of the goat, although no differences were evident on the HE-diet. An increase in slaughter age had no influence ($P>0.05$) on the proportional weight of the hearts. El Khider *et al.* (1998) also found no

Table 1. Proportional distribution (mean ± SE) of carcass, organs and tissue as a percentage of empty body weight in the BG kids and MM lambs receiving either a low or a high energy diet for 28 or 56 days

	BGLE28[1)] (n=8)	BGHE28[2)] (n=8)	MMLE28[3)] (n=8)	MMHE28[4)] (n=8)	BGLE56[1)] (n=8)	BGHE56[2)] (n=7)	MMLE56[3)] (n=8)	MMHE56[4)] (n=8)
Empty body weight (kg)	24.17[b] ± 1.299	27.85[ab] ± 1.299	30.58[a] ± 1.299	34.43[ce] ± 1.299	27.54[ab] ± 1.299	31.10[ac] ± 1.388	35.05[e] ± 1.299	41.86[d] ± 1.299
Heart	0.430[b] ± 0.0233	0.501[a] ± 0.0233	0.525[ac] ± 0.0233	0.540[ac] ± 0.0233	0.474[ab] ± 0.0233	0.484[ab] ± 0.0249	0.571[c] ± 0.0233	0.519[ac] ± 0.0233
Liver	2.47[a] ± 0.071	2.42[a] ± 0.071	2.01[bc] ± 0.071	2.08[bc] ± 0.071	2.20[b] ± 0.071	2.16[b] ± 0.076	2.13[b] ± 0.071	1.89[c] ± 0.071
Lungs & trachea	1.48[a] ± 0.102	1.44[a] ± 0.102	1.61[ac] ± 0.102	1.90[c] ± 0.102	1.60[ab] ± 0.102	1.81[bc] ± 0.109	1.66[ac] ± 0.102	1.81[bc] ± 0.102
Spleen	0.195[a] ± 0.0192	0.218[a] ± 0.0192	0.238[ab] ± 0.0192	0.233[ab] ± 0.0192	0.234[ab] ± 0.0192	0.203[a] ± 0.0205	0.273[b] ± 0.0192	0.241[ab] ± 0.0205
Empty stomach	5.54[b] ± 0.166	4.51[ac] ± 0.166	4.76[c] ± 0.166	4.15[ae] ± 0.166	4.70[c] ± 0.166	4.08[ae] ± 0.177	3.77[e] ± 0.166	3.23[d] ± 0.166
Empty intestines	5.55[a] ± 0.276	5.63[a] ± 0.276	5.65[a] ± 0.276	5.44[a] ± 0.276	3.83[b] ± 0.276	3.40[b] ± 0.295	3.40[b] ± 0.276	3.32[b] ± 0.276
Stomach contents	22.02[c] ± 1.163	17.68[ad] ± 1.163	19.92[cd] ± 1.163	15.35[ab] ± 1.163	18.61[ad] ± 1.163	12.74[b] ± 1.243	17.57[ad] ± 1.163	12.36[b] ± 1.163
Intestine contents	6.11[b] ± 0.422	5.04[ab] ± 0.422	6.20[b] ± 0.422	4.72[a] ± 0.422	6.11[b] ± 0.422	4.33[a] ± 0.451	6.66[b] ± 0.422	4.43[a] ± 0.422
Kidneys	0.442[b] ± 0.0145	0.415[ab] ± 0.0145	0.387[ade] ± 0.0145	0.365[ce] ± 0.0145	0.425[bd] ± 0.0145	0.381[ac] ± 0.0155	0.398[ade] ± 0.0145	0.341[c] ± 0.0145
Kidney fat	0.499[b] ± 0.1205	1.110[a] ± 0.1205	0.438[b] ± 0.1205	1.336[ad] ± 0.1205	1.428[ac] ± 0.1205	1.423[ac] ± 0.1288	1.606[cd] ± 0.1205	1.719[c] ± 0.1205
GIT fat	1.259[a] ± 0.2727	1.810[a] ± 0.2727	1.484[a] ± 0.2727	1.675[a] ± 0.2727	3.112[c] ± 0.2727	4.062[b] ± 0.2916	2.903[c] ± 0.2727	3.694[bc] ± 0.2727

Table 1. Proportional distribution (mean ± SE) of carcass, organs and tissue as a percentage of empty body weight in the BG kids and MM lambs receiving either a low or a high energy diet for 28 or 56 days (continue)

	BGLE28[1)] (n=8)	BGHE28[2)] (n=8)	MMLE28[3)] (n=8)	MMHE28[4)] (n=8)	BGLE56[1)] (n=8)	BGHE56[2)] (n=7)	MMLE56[3)] (n=8)	MMHE56[4)] (n=8)
Skin	8.35[a] ± 0.277	6.37[a] ± 0.277	9.77[b] ± 0.277	9.69[b] ± 0.277	8.62[a] ± 0.277	8.04[a] ± 0.296	11.33[c] ± 0.277	10.22[b] ± 0.277
Head	7.62[b] ± 0.207	6.88[ae] ± 0.207	6.21[d] ± 0.207	5.40[c] ± 0.207	7.50[b] ± 0.207	7.18[ab] ± 0.221	6.49[de] ± 0.207	5.62[c] ± 0.207
Feet	3.56[b] ± 0.084	3.26[a] ± 0.084	3.01[df] ± 0.084	2.76[ce] ± 0.084	3.23[ad] ± 0.084	3.19[ad] ± 0.090	2.82[ef] ± 0.084	2.58[c] ± 0.084
Edible offal[5)]	17.86[ab] ± 0.410	18.04[a] ± 0.410	17.09[ab] ± 0.410	17.72[ab] ± 0.410	18.00[a] ± 0.410	18.00[a] ± 0.439	17.71[b] ± 0.410	16.76[b] ± 0.410
Non-edible offal[6)]	19.53[ac] ± 0.436	18.51[ab] ± 0.436	18.99[ab] ± 0.436	18.42[ab] ± 0.436	19.35[a] ± 0.436	18.41[ab] ± 0.436	20.64[c] ± 0.436	18.42[ab] ± 0.436

[1)]BGLE28/56: Low Energy diet, fed to Boer goats for 28/56 days;
[2)]BGHE28/56: High Energy diet, fed to Boer goats for 28/56 days
[3)]MMLE28/56: Low Energy diet, fed to Mutton merinos for 28/56 days;
[4)]MMHE28/56: High Energy diet, fed to Mutton merinos for 28/56 days
[5)]Edible offal is defined as the sum of the heart, liver. lungs & trachea, spleen, stomach, intestines, kidneys, kidney fat and GIT-fat as a percentage of EBW
[6)]Non-edible offal is defined as the sum of the skin, head and feet as a percentage of EBW
[a,b,c] Means in the same row with different superscripts differ ($P<0.05$)

significant differences in the weight of the hearts of Sudanese desert goats and sheep when fed a feedlot diet.

Except for the LE56-day group, the weight of the liver (as a % of EBW) was higher in the goats than in the sheep, but Gaili & Ali (1985) found no significant differences and El Khider *et al.* (1998) found the liver of the goat to be lighter ($P<0.01$) than that of sheep.

MMHE28's proportional weight of the lungs & trachea were significantly higher than that of BGHE28. Except for that, species had no influence on the weight (as a % of EBW) of these organs. In Gaili & Ali's (1985) study the pluck of the sheep was less ($P<0.05$) than that of the goat, while El Khider *et al.* (1998) found that the lungs, diaphragm and trachea of sheep were higher ($P<0.05$) than that of goats. Neither in our investigation, nor in that of Gaili & Ali (1985) was the weight of the spleen influenced by species, although El Khider *et al.* (1985) found the spleen of the sheep to be significantly heavier.

Diet had an influence on the proportional weight of the empty stomach, with that from animals on a HE-diet being significantly heavier than their contemporaries on a LE-diet. There was a tendency for goats to have significantly heavier empty stomachs (as a percentage of EBW) than sheep, but there was no difference ($P>0.05$) between the empty intestine weights of goats and sheep. Both the proportional stomach weight and the proportional intestine weight decreased with an increase in slaughter age. Gaili & Ali (1985) found the alimentary tract of desert goats to be significantly heavier than that of desert sheep, but El Khider *et al.* (1998) found the exact opposite.

After 28 days in the feedlot, the goats' proportional kidney weight was significantly greater than that of the sheep, but after 56 days no difference ($P>0.05$) could be found. El Khider *et al.* (1998) found the kidneys of desert sheep to be heavier ($P<0.05$) than that of desert goats.

Kidney fat showed a diet x species x slaughter age interaction, because after 28 days the animals on the HE-diet had significantly more kidney fat than those on the LE-diet, but after 56 days no difference ($P>0.05$) was evident. In another section of this investigation (Sheridan, Hoffman & Ferreira, 2001b) the same trend was found with the 8-9-10-rib cuts. Therefore it is reasonable to assume that both kidney fat and subcutaneous fat deposition occurred earlier in animals on the HE-diet than those on the LE-diet, which is a possible indication that the HE-diet had excess energy than that needed for growth and maintenance.

Statistically GIT-fat was not influenced by species, within a diet. However, there was a tendency (especially on the HE-diet) for goats to store more fat abdominally than sheep. Gaili & Ali (1985) concluded that goats respond to fattening by depositing more fat in the omentum and mesentry than sheep and that sheep deposited more fat in the carcass. Both kidney fat and GIT-fat was influenced by slaughter age with the 56-day animals having more ($P<0.05$) fat that their contemporaries slaughtered after 28 days.

The skins (as a % of EBW) of the MM's were significantly heavier than that of the BG's, probably due to wool growth. This agrees with the findings of both Gaili & Ali (1985) and El Khider *et al.* (1998). The BG's in our investigation had significantly heavier heads and feet (% of EBW) than the MM's. This is in contrast with the findings of Gaili & Ali (1985) who stated that the weight of the head and feet did not differ significantly between desert goats and sheep at an equally adjusted EBW. However, as in this investigation, El Kihder *et al.* (1998) also found the feet of goats to be heavier ($P<0.05$) than that of sheep (g/kg EBW). The reason for the lighter heads of the MM's in the present investigation, is probably the absence of horns.

The proportional weight of the BGLE28's feet was significantly higher than that of BGLE56. Apart form that, age had no influence ($P>0.05$) on the proportional weight of the heads and feet within a treatment group. This seems strange, because both the head and feet are early maturing parts of the body. Shemeis, Liboriussen, Bech Anderson & Abdallah (1994) found that as animals age, the proportional weights of the head, feet and skin decrease. A possible explanation why similar results were not found in this investigation, could be that the differences in age of the two slaughter groups was too small (28 days) for an effect to manifest itself.

The non-edible offal of the MMLE56 is higher than expected. Apart from that, neither species, nor slaughter age influenced the proportional weight of the non-edible offal. After 28 days in the feedlot, there was no difference ($P>0.05$) between the proportional weight of the edible offal of goats and sheep. However, after 56 days BG's had significantly more edible offal (as a % of EBW) than MM's. According to Riley, Savell, Shelton & Smith (1989) "internal offal" (as opposed to "external offal") adds to the meat production potential of the animal.

In Table 2 the maximum length, breadth and depth of the carcasses are noted. Neither species nor diet influenced the length of the carcasses, but the animals slaughtered after 56 days in the feedlot had significantly longer carcasses than their contemporaries slaughtered after 28 days. Within species, diet had no influence on the breadth of the carcasses. However, species had an influence, with the MM having significantly broader carcasses than the BG's. BGHE28 had a deeper carcass than BGLE28, but apart form that, diet did not influence the depth within a species. However, the MM's had significantly deeper carcasses than the BG's. Days spent in the feedlot also increased the depth of the carcasses.

When the relationship between carcass weight and length was determined it was evident that species did have a significant effect on this relationship, with MM's having more weight per unit carcass length than BG's. This confirms the belief that goats are leaner animals than sheep. In both species the weight:length-relationship stayed constant with an increase in slaughter age. Except for the BGHE56, which has a lower relationship than was expected, diet had a significant influence, with the HE-animals having more weight per unit carcass length, probably due to subcutaneous fat.

Table 2. Maximum length, breadth and depth of the carcasses of the BG kids and MM lambs (mean ± SE)

	BGLE28[1)] (n=8)	BGHE28[2)] (n=8)	MMLE28[3)] (n=8)	MMHE28[4)] (n=8)	BGLE56[1)] (n=8)	BGHE56[3)] (n=8)	MMLE56[3)] (n=8)	MMHE56[4)] (n=6)
Length (cm)	92.80[a] ± 2.103	94.90[a] ± 2.103	88.43[a] ± 2.103	92.15[a] ± 2.103	110.48[b] ± 2.103	113.88[b] ± 2.103	112.61[b] ± 2.103	113.45[b] ± 2.428
Breadth (cm)	23.09[a] ± 0.519	22.45[a] ± 0.519	24.49[bd] ± 0.519	25.89[cd] ± 0.519	23.76[ab] ± 0.519	23.99[b] ± 0.519	26.04[c] ± 0.519	26.83[c] ± 0.599[c]
Depth (cm)	23.31[b] ± 0.538	25.43[ac] ± 0.53	26.46[ac] ± 0.538	26.90[c] ± 0.538	24.99[a] ± 0.538	25.28[a] ± 0.538	27.80[cd] ± 0.538	28.72[d] ± 0.538
Weight:Length (kg/cm)	0.14[b] ± 0.007	0.17[ad] ± 0.007	0.18[d] ± 0.007	0.21[c] ± 0.007	0.14[b] ± 0.007	0.15[ab] ± 0.007	0.18[d] ± 0.007	0.22[c] ± 0.008

[1)]BGLE28/56: Low Energy diet, fed to Boer goats for 28/56 days

[2)]BGHE28/56: High Energy diet, fed to Boer goats for 28/56 days

[3)]MMLE28/56: Low Energy diet, fed to Mutton merinos for 28/56 days

[4)]MMHE28/56: High Energy diet, fed to Mutton merinos for 28/56 days

[a,b,c] Means in the same row with different superscripts differ (P<0.05)

Table 3 shows the weight of the commercial cuts as a percentage of carcass weight. Diet did not influence (P>0.05) any of the BG carcass' parameters measured. However, the HEMM's had both heavier carcasses, as well as heavier flanks and lighter buttocks (as percentage of carcass weight) than the LEMM's.

Species did not significantly influence the proportions of the neck, breast or thick rib, when expressed as a percentage of the carcass. However, there was a tendency for the fore limb to be more developed in goats than in sheep. This agrees with the work of Casey (1982) on MM's, Merinos, Dorpers, Pedi sheep and BG's. Gaili & Ali (1985) too found the muscles of the neck, thorax and forelimb regions were more developed in yearling goats than in yearling sheep.

On the LE-diet, the sheep had heavier carcasses, and proportionally heavier ribs and buttocks than the goats, but BGLE had heavier flanks than MMLE. On the HE-diet the MM's had heavier carcasses, ribs, loins and buttocks than the BG's. This agrees with the findings of Gaili & Ali (1985) who states that yearling sheep had better developed hindquarter muscles than goats.

Muscles such as those in the hindleg and loin have less associated fat and connective tissue and therefore contribute to the higher-priced cuts of the carcass (Thonney *et al.*, 1987). Since the LEMM have heavier buttocks than the LEBG and the HEMM have heavier buttocks and loins than the HEBG, one can expect higher prices for sheep carcasses than for that of goats.

As has been reported previously (Sheridan *et al.*, 2001a) the MM's in this investigation had significantly higher average daily gains (ADG) than the BG's (BGLE56: 0.152; BGHE56 0.162; MMLE56: 0.203; MMHE56: 0.281 kg/day). However, in terms of feed conversion efficiency (FCE), there was no difference (P>0.05) between BG's and MM's within a diet (BGLE56: 9.09; BGHE56: 6.62; MMLE56: 9.40; MMHE56: 6.47 kg feed/kg weight gain). While the FCE of BGLE did not differ from BGHE, MMHE was more efficient (P<0.05) than MMLE. The fact that BG's had lower ADG's, but not lower FCE's than MM's as well as the fact that diet did not influence (P>0.05) their carcass weight distribution suggest that BG's may be suitable for feedlot finishing on a LE-diet when the overhead costs are justifiably low.

Table 3. Commercial cuts (mean ± SE) as a percentage of carcass weight of BG kids and MM lambs, slaughtered after 56 days in the feedlot and receiving either a low energy or high energy feedlot diet

	BGLE56[1)] (n=8)	BGHE56[2)] (n=7)	MMLE56[3)] (n=8)	MMHE56[4)] (n=8)
Carcass weight (kg)	$15.28^a \pm 0.642$	$17.05^a \pm 0.686$	$19.87^b \pm 0.642$	$24.01^c \pm 0.642$
Neck	$4.16^a \pm 0.284$	$3.71^a \pm 0.303$	$3.62^a \pm 0.284$	$3.51^a \pm 0.284$
Breast	$17.68^a \pm 0.618$	$17.21^{ab} \pm 0.661$	$16.02^{ab} \pm 0.618$	$15.60^b \pm 0.618$
Thick rib	$14.84^a \pm 0.523$	$13.97^a \pm 0.559$	$13.45^a \pm 0.523$	$13.36^a \pm 0.523$
Rib	$10.51^a \pm 0.435$	$10.62^a \pm 0.465$	$12.32^b \pm 0.435$	$12.05^b \pm 0.435$
Loin	$8.33^{ab} \pm 0.460$	$7.46^a \pm 0.492$	$9.25^b \pm 0.460$	$8.99^b \pm 0.460$
Flank	$14.83^a \pm 0.467$	$14.66^a \pm 0.499$	$12.31^b \pm 0.467$	$13.70^a \pm 0.467$
Buttock	$29.85^a \pm 0.444$	$28.61^a \pm 0.474$	$32.98^b \pm 0.444$	$31.65^c \pm 0.444$

[1)]BGLE56: Low Energy diet, fed to Boer goats for 56 days
[2)]BGHE56: High Energy diet, fed to Boer goats for 56 days
[3)]MMLE56: Low Energy diet, fed to Mutton merinos for 56 days
[4)]MMHE56: High Energy diet, fed to Mutton merinos for 56 days
[a,b,c] Means in the same row with different superscripts differ ($P<0.05$)

CONCLUSION

The mass of the liver, empty stomach, head, and feet as a proportion of empty body weight, was higher in goats than in sheep. The MM's had significantly heavier skins, probably due to wool growth. After 56 days, goats had a significantly higher proportion of edible offal than sheep. Both kidney fat and GIT fat increased with an increase in the age of both species. Neither species nor diet influenced the length of the carcasses, although, as expected, the animals slaughtered after 56 days in the feedlot had significantly longer and deeper carcasses than their contemporaries slaughtered after 28 days. Within a species, diet did not influence the breadth of the carcasses. However, species had an influence with the MM having significantly broader and deeper carcasses than the BG's. The goats had less weight per unit carcass length and thus more slender carcasses than the sheep. HE-animals had more weight per unit carcass length than LE-animals, probably due to subcutaneous fat. MM's had heavier carcasses and proportionally heavier ribs and buttocks than BG's. As the hindquarter is the most expensive commercial cut, lamb carcasses may give better returns in retail markets than kid carcasses. One implication of these results may be that the goat should be dealt with as an entity in the market place and not be compared to lamb and mutton carcasses. However, since diet did not influence the carcass weight distribution of BG's, goats can be finished on a LE-diet in the feedlot, without compromising the commercial yield of the carcass. These results may render the BG economically viable for feedlot finishing.

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NUTRITIONAL MEAT VALUE OF BOER GOAT KIDS AND SA MUTTON MERINO LAMBS RECEIVING EITHER A LOW OR A HIGH ENERGY FEEDLOT DIET

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ABSTRACT

The proximate chemical composition, amino acid and mineral contents of the meat of 32 Boer goat (BG) kids and 32 South African Mutton merino (MM) lambs were investigated. Two pelleted diets (fed to 16 animals/species) with either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) metabolisable energy level were fed individually, *ad lib*, to the animals for either 28 or 56 days, after which the animals were slaughtered. The *m. semimembranosus* and 8-9-10-rib cut of each carcass were dissected and used for chemical analysis. Neither diet nor slaughter age influenced the proximate analysis of the *m. semimembranosus*, but MM's had significantly lower moisture values than BG's. In the 8-9-10-rib cuts BG's had significantly more moisture and protein and lower fat and energy values than MM's. DM, fat and energy values increased with an increase in slaughter age in both species. BG's had significantly higher concentrations of 11 of the 18 measured essential amino acids in their 8-9-10-rib cuts than the MM. Goat carcasses had higher Ca, K, Mg, Na and P-levels than sheep carcasses, regardless of the diet fed. There was a tendency for goat's *m. semimembranosus* to have a lower Fe-content than that of sheep. It can be concluded that chemically the meat from young feedlot goats is not inferior to that of lamb, and since it has a higher protein percentage and lower fat percentage it can be considered as a healthy food commodity.

Key words: proximate chemical composition, amino acid contents, mineral contents, diet energy content.

INTRODUCTION

Some 60% of the world population, particularly in developing countries, are thought to be suffering from some sort of animal protein shortage. Exploitation of unconventional livestock such as goats is advocated as a means of increasing meat production and consumption (Babiker, El Khider & Shafie, 1990). Goat populations in developing countries represent 94% of the world total. Despite their numerical importance goat meat (chevon) is little consumed and commands a low price compared to beef and lamb or mutton. This is attributed to a general belief that goat meat is inferior to mutton and beef (Babiker *et al.*, 1990).

However, Gaili & Ali (1985) and Babiker *et al.* (1990) concluded that chemically, goat meat obtained from young fattened animals is not inferior to lamb and due to its low price it could replace lamb and mutton, particularly among low-income groups. It is a good raw material for comminuted meat products and since it has a high protein value and low fat content, it is a healthy food commodity and suitable for people on a restricted calorie intake (Gaili & Ali, 1985).

Meat is a very important source of minerals in the human diet and most of the naturally occurring mineral elements are found in animal tissues (McDonald, Edwards & Greenhalgh, 1988; Park, 1990). Nearly all the essential mineral elements, both major and trace, are believed to have one or more catalytic functions in the cell (McDonald *et al.*, 1988). However, the information on the mineral content of goat meat is rare.

The potential of the Boer goat (BG) as a meat-producing animal has been recognized by early researchers such as Owen & Norman (1977) and Casey (1983). However, little is known about the performance of goats under intensive/feedlot conditions and the effect thereof on the chemical composition of chevon.

The South African Mutton merino (MM) was selected as a standard to compare with the BG for this investigation. The MM is a dual-purpose breed, developed to produce a slaughter lamb at an early age. It has a high fertility, good conformation, good feed conversion ratio and adaptability and is therefore popular in feedlot production systems.

Information on the role of nutrition on the body composition of goats is important, as it may be possible to manipulate composition to meet particular market requirements. Thus, the present investigation was conducted to determine the influence of diet energy level and days spent in the feedlot on the chemical composition of BG meat in comparison to that of MM's.

MATERIALS AND METHODS

Thirty-two BG kids and 32 MM lambs were used for this investigation. All the animals were castrated and weaned before entering the feedlot. The average initial body weight of the kids and lambs were 26.23 ± 3.86 kg and 32.72 ± 2.13 kg, respectively. The animals were randomly allocated to four treatment groups of eight animals per species and housed individually in an enclosed but adequately ventilated shed with a slatted floor. The individual pens were built of a material that allowed adjacent animals so see and interact with each other. The investigation was conducted between October and December 1999 on the experimental farm of the University of Stellenbosch, South Africa. Two pelleted diets were formulated according to the NRC (1985) recommendations for lambs, on an isonitrogenous basis (14.4% crude protein (CP) on a DM basis) to contain either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) calculated metabolisable energy level (Table 1). The animals

Table 1. Ingredients and chemical composition of the two diets fed to BG kids and MM lambs

Item	Low Energy Diet	High Energy Diet
Ingredients[1]	**%**	**%**
Wheat Bran	1.50	0.00
Maize Meal	30.00	38.00
Sunflower Oilcake	1.64	4.46
Groundnut Oilcake	3.33	0.00
Limestone	0.07	0.58
Urea	0.70	0.59
Maize Germ[2]	0.00	9.31
Supermax Premix[3]	0.00	10.45
Vit/Min Premix [4]	0.21	0.21
Mono Calcium Phosphate	0.00	0.11
Salt	0.50	0.50
Citrus Ruminant Flavour	0.02	0.02
Ammonium Chloride	0.75	0.75
Taurotec[5]	0.03	0.03
NaOH Wheat Straw	21.26	15.00
Lucerne Hay	35.00	15.00
Molasses Cuber	5.00	5.00
Chemical composition[6]	**Content**	**Content**
Ash (%)	9.49	8.44
Crude Fat (%)	2.18	5.59
Crude Protein (%)	14.29	14.56
ADF (%)	24.74	17.78
NDF (%)	44.17	35.92
ME (MJ/kg) [7]	8.90	10.90
Calcium (%)	0.44	0.74
Phosphorus (%)	0.27	0.36

[1]On an air dry basis; [2]Supplied by Cape Oil (Berkleyroad, Box 16, Maitland); [3]Rumen inert fat; supplied by Marine Oil (Division Tiger Food, Mainroad Didovalley, Simons Town); [4]A standard mineral (macro and micro) and vitamin supplement formulated by Meadow Feed Mills accoding to the NRC (1985); [5]A growth promoter; supplied by Roche (Wycroftroad, Box 13167, Mowbray); [6]Analysed values on a DM basis; [7]Based on the nutritive value of feeds according to laboratory determined values by Meadow Feed Mills (Westhovenstr Bos 262, Paarl)

received the diets and water *ad lib*. After 28 days, 16 BG's and 16 MM's were slaughtered, while the rest of the animals continued in the trial until day 56, when they were slaughtered. The feedlot performance of the animals has been reported (Sheridan, Ferreira & Hoffman, 2001).

When slaughtered, the animals were first stunned electronically (200V for 10s). After exsanguination the carcasses were hung to bleed. The carcasses were eviscerated using standard procedures and then hung in a cooler (4°C) for 24 hours.

On the right hand side of the carcass, the *longissimus dorsi* rib samples were cut from the 8'th to 10'th thoracic vertebrae and the *m. semimembranosus* was dissected from the left hind leg.

The 8-9-10-rib cuts included bone, fat and meat. The meat samples were minced twice through a 2 mm plate, vacuum packed and stored at -13°C for later chemical analysis. Proximate composition of the *m. semimembranosus* and 8-9-10-rib cut were determined according to the AOAC (1995). The analysis included determination of moisture, protein (N x 6.25) and ash. The lipid content was determined by solvent extraction according to the method of Lee, Trevino & Chaiyawat (1996).

Amino acids were determined on dried, fat free samples of the 8-9-10-rib cuts by ion-exchange chromatography of the acid-hydrolysed protein. Samples of each muscle were hydrolysed (AOAC, 1995) with 6 M HCl in a sealed tube under N_2 for 22 h in an oil bath at 110°C. A Beckman amino acid analyser (Model 6600) was used for separating amino acids using sodium citrate buffers. Only six BG's and six MM's fed the HE-diet for 56 days were used for amino acid analysis.

Minerals were determined on the *m. semimembranosus* and 8-9-10-rib cuts of all the animals, according to method IIA of Watson (1994). Element concentrations were measured on an ICP-AES (Inductive Coupled Plasma Atomic Emission Spectrophotometer; Liberty Series AA Varian).

Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1990). The following model was used to determine the presence of the three-way interaction:

$Y_{ijk} = \mu + S_i + D_j + A_k + SD_{ij} + SA_{ik} + DA_{jk} + SDA_{ijk} + e_{ijk}$

Y_{ijk} = Dependent variable of the i'th species of the j'th diet of the k'th slaughter age

μ = Overall mean

S_i = Species effect

D_j = Diet effect

A_k = Slaughter age effect

SD_{ij} = Species-diet interaction

SA_{ik} = Species-slaughter age interaction

DA_{jk} = Diet-slaughter age interaction

SDA_{ijk} = Species-diet-slaughter age interaction

e_{ijk} = Random error of measurement term

The differences between the diets, species and slaughter ages were, where appropriate, tested separately by means of the null hypotheses (H_0), with $H_0{:}\mu=\mu_0$ and the alternate hypothesis (H_a) being $H_a{:}\mu\neq\mu_0$. This was done by means of contrast analyses and estimated least square means (± SE). Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$) for diet, species or age.

RESULTS AND DISCUSSION

The determination of carcass chemical composition is important when nutritional, physiological or genetic differences are to be evaluated. To be able to do this without sacrificing the entire carcass, several authors (Kirton & Barton, 1962; Crouse & Dikeman, 1974; Nour & Thonney, 1994) have considered the three-rib cut to be a useful predictor of total carcass chemical composition.

Unless otherwise indicated, no significant interactions between diet, species and slaughter age were present. The proximate composition of the *m. semimembranosus* and 8-9-10-rib cuts are presented in Table 2. Within species, neither diet, nor slaughter age had an influence (P>0.05) on the moisture content of the *m. semimembranosus* of the animals. However, lamb had less moisture than chevon. Neither percentage ash, nor protein was influenced (P>0.05) by diet, species or slaughter age. The fat content of BGLE56 is significantly lower than that of BGHE56. Except for that, within a species, diet did not have an influence (P>0.05) on the fat percentage in the *m. semimembranosus*. There was a tendency for sheep to have a higher muscle fat percentage than goats on the same diet. A possible explanation why the 56-day animals, within a species, did not have significantly more fat in the muscles than the 28-day animals, is because marbling fat (intramascular fat) starts developing only after kidney, intermuscular and subcutaneous fat has been formed. The animals in this study were relatively young (approximately 5 months) and therefore marbling fat have not developed to a significant amount yet. However, there was a trend for animals on the HE-diet to have more fat (and consequently a higher calculated energy value) in the muscle after 56 days than after 28 days. This is probably an indication that the HE-diet had excess energy for growth and maintenance, which was absorbed and deposited as fat.

MMHE56 had a higher (P=0.0468) calculated energy value than MMLE56, but apart from that, within a treatment non of the other main effects showed any other significant difference (e.g. energy content).

Babiker *et al.* (1990) found that chemically goat meat had significantly less intramuscular fat and significantly more moisture than lamb. As in our investigation, El Khider, Babiker & Shafie (1998) reported that protein and ash content were similar in the meat from goats and sheep.

In terms of the proximate composition of the 8-9-10-rib cuts, the goats had a significantly higher moisture content than the sheep. However, within species moisture content showed an interaction, after 28 days animals on the LE-diet had significantly more moisture than their contemporaries on the HE-diet, but after 56 days, no differences occurred. This can be attributed to the fact that after 28 days the animals on the HE-diet had more fat than those on the LE-diet, but after 56 days (within a species) there was no difference (P>0.05) in fat content between the animals on the LE-diet and those on the HE-diet. After 56 days in the feedlot, the animals had a lower (P<0.05) moisture content than after 28 days. This too can probably be

Table 2. Proximate analysis (on an *as is* basis) of *m. semimembranosus* and 8-9-10-rib cut of the BG kids and MM lambs fed either a low or a high energy diet, for 28 or 56 days

	BGLE28[1] (n=8)	BGHE28[2] (n=8)	MMLE28[3] (n=8)	MMHE28[4] (n=8)	BGLE56[1] (n=8)	BGHE56[2] (n=8)	MMLE56[3] (n=8)	MMHE56[4] (n=8)	SE
m. semimembranosus									
Moisture (%)	77.48^{b}	76.49^{ab}	74.51^{cd}	73.92^{c}	76.33^{ab}	75.61^{ad}	74.92^{cd}	73.89^{c}	0.435
Ash (%)	1.26	1.30	1.35	1.28	1.32	1.41	1.47	1.07	0.091
Protein (%)	18.83	18.69	18.67	19.52	19.23	19.10	19.01	19.70	0.497
Fat (%)	2.51^{b}	2.68^{ab}	3.13^{ac}	3.19^{ac}	2.35^{b}	3.25^{ad}	3.06^{ac}	3.65^{cd}	0.242
Energy (kJ)[5]	413.12^{a}	416.99^{ab}	433.06^{ab}	449.78^{bc}	413.69^{a}	445.10^{abc}	436.34^{ab}	469.89^{c}	11.667
8-9-10-rib cut									
Moisture (%)	65.14^{c}	62.13^{a}	54.70^{f}	50.21^{d}	59.47^{ab}	58.97^{b}	45.37^{e}	43.96^{e}	0.941
Ash (%)	3.39	3.30	2.99	3.05	2.94	3.26	2.90	2.88	0.203
Protein (%)	17.68^{a}	17.17^{a}	15.26^{b}	14.64^{b}	17.00^{a}	17.30^{a}	13.41^{c}	12.99^{c}	0.328
Fat (%)	13.47^{b}	17.57^{a}	24.47^{f}	30.31^{d}	21.24^{cf}	20.22^{ac}	35.49^{e}	36.85^{e}	1.169
Energy (kJ)[5]	798.82^{b}	941.89^{a}	1164.73^{f}	1370.48^{d}	1074.97^{cf}	1042.33^{ac}	1540.93^{e}	1584.19^{e}	40.096

[1] BGLE28/56: Low Energy diet, fed to Boer goats for 28/56 days
[2] BGHE28/56: High Energy diet, fed to Boer goats for 28/56 days
[3] MMLE28/56: Low Energy diet, fed to Mutton merinos for 28/56 days
[4] MMHE28/56: High Energy diet, fed to Mutton merinos for 28/56 days
[5] Total energy (kJ) = (g protein in 100g sample x 17) + (g fat in 100g sample x 37) (As gazetted: SA Act No 54 of 1972)
^{a,b,c} Means in the same row with different superscripts differ ($P<0.05$)

ascribed to the fact that the animals had more fat and therefore relatively less moisture and protein after 56 days in the feedlot.

Within species, diet did not influence (P>0.05) the protein content of the meat, probably because the diets were isonitrogenous. BG's had significantly higher protein levels in their 8-9-10-rib cut than MM's and only the MM's protein content in the 8-9-10-rib cut decreased with an increase in age. This can probably be explained by the fact that MM's had significantly more fat and therefore relatively less meat (protein) in their 8-9-10-rib cuts than BG's and that the fat content in MM's increased at a faster rate with an increase in slaughter age, compared to BG's.

As mentioned, after 28 days in the feedlot, the carcasses of the animals on the HE-diet were significantly fatter than their contemporaries on the LE-diet. However, after 56 days there was no difference (P>0.05) between the animals (within species) on the LE-diet and those on the HE-diet.

Gaili & Ali (1985) concluded that the phenomenon that fattened goats had more protein and less intramuscular fat in their muscles than sheep, could be ascribed to a greater rate of protein synthesis during the feeding period in goats than in sheep. Sheep responded to nutritional treatment by depositing more fat and goats responded by laying down more muscle protein. When the energy values of the meat were calculated in this investigation, the exact same patterns were evident as with the fat content which is partly due to the fact that fat percentage contributes largely to the calculation of the energy value of the meat. Therefore it is reasonable to accept that BG carcasses have less fat and a lower energy value than that of mutton carcasses and is therefore suitable for people wishing to consume a low calorie diet.

The *m. semimembranosus* had higher levels of moisture and protein and less ash and fat than the 8-9-10-rib cut. One reason is because the 8-9-10-rib samples included the bone, which both raises the ash content and lowers the relative meat (protein) content. The 8-9-10-rib cut also contains subcutaneous, intermuscular and intramusclular fat, while the *m. semimembranosus* contains only intramuscular fat and trace amounts of intermuscular fat. Subcutaneous fat develops earlier than intermuscular fat and therefore the 8-9-10-rib cuts have a higher fat percentage.

The amino acid (AA) compositions of the 8-9-10-rib cuts of the BGHE56 and MMHE56 are presented in Table 3. On a g AA/100 g 8-9-10-rib cut basis, aspartic, glutamic, glycine, leucine and lysine were the most prominent amino acids in both the mutton and the goat meat. BG's 8-9-10-rib cuts had a significantly higher concentration of 11 of the 18 measured amino acids compared to that of the MM. However, MM's had higher tryptohan levels than BG's (0.31% vs. 0.22%), while there was no significant difference between the serine, glysine, alanine, histidine, arginine and cystine levels in BG and MM 8-9-10-rib cuts. Srinivasen &

Table 3. Amino acid composition (g AA/100g 8-9-10-rib cut) of the 8-9-10-rib cuts BG's and MM's, receiving a high energy diet for 56 days

Amino acid	BGHE56[1)] (n=6)	MMHE56[2)] (n=6)	SE
Aspartic acid	2.03[a]	1.89[b]	0.041
Threonine	0.91[a]	0.83[b]	0.019
Serine	0.58	0.51	0.025
Glutamic acid	3.16[a]	2.91[b]	0.059
Proline	0.74[a]	0.54[b]	0.061
Glycine	1.68	1.67	0.058
Alanine	1.28	1.14	0.060
Valine	1.19[a]	1.04[b]	0.024
Methionine	0.49[a]	0.44[b]	0.012
Isoleucine	1.03[a]	0.92[b]	0.025
Leucine	1.75[a]	1.59[b]	0.039
Tyrosine	0.63[a]	0.56[b]	0.017
Phenylalanine	0.91[a]	0.83[b]	0.020
Histidine	0.63	0.55	0.024
Lysine	1.76[a]	1.61[b]	0.044
Arginine	1.44	1.38	0.045
Cystine	0.30	0.30	0.010
Tryptophan	0.22[a]	0.31[b]	0.011

[1)]BGHE56: High Energy diet, fed to Boer goats for 56 days
[2)]MMHE56: High Energy diet, fed to Mutton merinos for 56 days
[a,b,c] Means in the same row with different superscripts differ ($P<0.05$)

Moorjanie (1974) reported that goat meat contains more arginine, leucine and isoleucine than mutton, but that the pattern of the remaining amino acids is similar to that of mutton.

The fact that goat carcasses have significantly more protein and essential amino acids than sheep carcasses is important in the light of exploitation of unconventional livestock. Sixty percent of the world population, particularly in developing countries, is thought to be suffering from some sort of animal protein shortage. Goat meat can therefore be advocated as a means of limiting this shortage, especially since goat populations in developing countries represent 94% of the world total (Babiker *et al.*, 1990).

The mineral composition of the *m. semimembranosus* and 8-9-10-rib cuts are represented in Table 4 and 5, respectively. There was no difference ($P>0.05$) in mineral content between the

Table 4. Mineral composition (mg/100g) (mean ± SE) of the *m. semimembranosus* of the BG kids and MM lambs fed either a low or high energy feedlot diet

	BGLE[1)] (n=16)	BGHE[2)] (n=16)	MMLE[3)] (n=16)	MMHE[4)] (n=16)
Ca	6.63	8.07	6.98	7.10
	± 0.538	± 0.538	± 0.521	± 0.538
I	46.432	44.28	46.59	49.78
	± 4.035	± 4.035	± 3.907	± 4.035
K	193.27[a]	218.57[b]	223.71[b]	215.27[b]
	± 7.571	± 7.571	± 7.331	± 7.571
Mg	23.03[a]	26.02[b]	25.13[ab]	26.50[b]
	± 0.798	± 0.798	± 0.772	± 0.798
Na	22.79[a]	25.93[ab]	29.78[c]	26.93[bc]
	± 1.203	± 1.203	± 1.65	± 1.203
P	154.74[a]	178.19[b]	170.36[b]	176.67[b]
	± 5.465	± 5.465	± 5.292	± 5.465
Cu	0.23[ab]	0.15[a]	0.22[ab]	0.30[b]
	± 0.048	± 0.053	± 0.046	± 0.048
Fe	0.75[a]	1.09[ab]	1.30[b]	1.28[b]
	± 0.122	± 0.118	± 0.114	± 0.118
Pb	0.023	0.028	0.028	0.030
	± 0.0036	± 0.0043	± 0.0034	± 0.0036

[1)]BGLE: Low Energy diet fed to Boer goats
[2)]BGHE: High Energy diet fed to Boer goats
[3)]MMLE: Low Energy diet fed to Mutton merinos
[4)]MMHE: High Energy diet fed to Mutton merinos
[a,b,c] Means in the same row with different superscripts differ ($P<0.05$)

animals slaughtered after 28 days and their contemporaries slaughtered after 56 days. Therefore the data was pooled and only diet and species were considered as main effects.

In the *m. semimembranosus* K was the macromineral with the highest concentration, followed by P. This agrees with the results of Park (1990). Ca, I and Pb concentrations in the *m. semimembranosus* was neither influenced by diet, nor by species. K-content showed a diet x species interaction, since BGLE's K-content was lower than that of BGHE, MMLE and MMHE (193.27, 218,569, 223.71 and 215.27 mg/100g, respectively).

Mg-concentration of the BGHE's *m. semimembranosus* was significantly higher than that of BGLE, but that of MMHE did not differ ($P>0.05$) from MMLE. Within a diet, species had no influence. Na-content too showed an interaction, because on the LE-diet MM's had significantly higher levels of this mineral than BG's, but on the HE-diet no difference ($P>0.05$) was evident. With the exception of BGLE's, neither diet, nor species had a significant influence on the P-content of the muscle. Within a species, neither Cu, nor Fe-content was influenced by diet. However, BGLE's Cu-content of the *m. semimembranosus* did not differ significantly from MMLE, but BGHE had lower (P<0.05) Cu-levels than BGHE. There was a tendency for MM's to have higher Fe-levels in the *m. semimembranosus*. This is in contrast with the data of the USDA (2001 a and b) who gives the iron content (mg/100g edible portion) of goat meat as 2.83mg/100g and that of sheep as 1.57mg/100g.

Table 5. Mineral composition (mg/100g) (mean ± SE) of the 8-9-10-rib cuts of the BG kids and MM lambs fed either a low or high energy feedlot diet

	BGLE[1)] (n=16)	BGHE[2)] (n=16)	MMLE[3)] (n=16)	MMHE[4)] (n=16)
Ca	880.84^{ab}	946.55^{a}	672.88^{c}	723.96^{bc}
	± 59.362	± 61.309	± 65.857	± 59.362
I	41.68^{ac}	43.38^{a}	36.56^{bc}	33.45^{b}
	± 2.048	± 2.115	± 2.272	± 2.048
K	141.57^{a}	130.88^{a}	95.46^{b}	86.16^{b}
	± 6.476	± 6.689	± 7.185	± 6.476
Mg	32.51^{a}	35.36^{a}	24.32^{b}	24.90^{b}
	± 1.594	± 1.646	± 1.768	± 1.594
Na	56.73^{a}	49.83^{ac}	42.39^{bc}	38.12^{b}
	± 3.415	± 3.527	± 3.788	± 3.415
P	631.97^{a}	653.69^{a}	485.39^{b}	510.38^{b}
	± 37.685	± 38.920	± 41.807	± 37.685
Cu	0.20^{a}	0.14^{ab}	0.11^{b}	0.13^{ab}
	± 0.027	± 0.032	± 0.030	± 0.027
Fe	1.19^{a}	1.78^{b}	1.19^{a}	1.01^{a}
	± 0.142	± 0.147	± 0.158	± 0.142
Pb	0.013	0.016	0.014	0.016
	± 0.0032	± 0.0029	± 0.0027	± 0.0039

[1)]BGLE: Low Energy diet fed to Boer goats

[2)]BGHE: High Energy diet fed to Boer goats

[3)]MMLE: Low Energy diet fed to Mutton merinos

[4)]MMHE: High Energy diet fed to Mutton merinos

[a,b,c] Means in the same row with different superscripts differ (P<0.05)

In the 8-9-10-rib cut both Ca and P levels were much higher than in the *m. semimembranosus*, due to the presence of the bone. Within a species, diet had neither an influence on the Ca- nor the P-levels, but both these two minerals had significantly higher concentrations in the goat's 8-9-10-rib cut than in that of the sheep. This is probably due to the fact that goats are leaner animals and therefore the bone proportion is relatively higher in goats than in sheep.

K-, Mg- and Na-levels were not influenced by diet within a species, but goats had higher concentrations of all three these minerals than sheep. The same tendency was evident for Cu-levels. I-concentration was not influenced by diet within a species and BGLE's concentration did not differ significantly from MMLE, but BGHE had significantly higher levels than MMHE.

Fe-content showed a diet x species interaction, where BGHE had a higher FE-concentration than was expected. As with the *m. semimembranosus*, only traces of Pb were present in the 8-9-10-rib cuts. Pb-content was neither influenced by species, nor by diet.

CONCLUSIONS

It can be concluded that goat carcasses from young feedlot animals are not inferior to that of lamb in terms of chemical composition. The BG's 8-9-10-rib cuts (and presumably the carcass) had significantly higher protein levels as well as significantly higher concentrations of 11 of the 18 measured essential amino acids. Goat meat can therefore be used as an important means to help limit the human population's global protein shortage, especially in developing countries. Goat carcasses had higher Ca, K, Mg, Na and P-levels than sheep carcasses, regardless of the diet fed. There was a tendency for goat's *m. semimembranosus* to have a lower Fe-content than that of sheep. Due to its low price in the abattoir, goat meat can replace lamb and mutton, particularly among low-income groups. Since it has a lower fat percentage and energy value and higher protein percentage than sheep, goat carcasses can be considered as a healthy food commodity suitable for people wishing to consume a low calorie diet.

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FATTY ACID PROFILE AND CHOLESTROL CONTENT OF THE MEAT OF BOER GOAT KIDS AND SA MUTTON MERINO LAMBS RECEIVING EITHER A LOW OR A HIGH ENERGY FEEDLOT DIET

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ABSTRACT

The fatty acid and cholesterol composition of the meat of 32 Boer goat (BG) kids and 32 South African Mutton merino (MM) lambs were investigated. Two pelleted diets (fed to 16 animals/species) with either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) metabolisable energy level were fed individually, *ad lib*, for either 28 or 56 days, after which the animals were slaughtered. The *m. semimembranosus* and 8-9-10-rib cut of each carcass were dissected and used for chemical analysis. BG's had a lower carcass cholesterol content than lamb (66.77 vs. 99.28 mg/100g, respectively). Palmitic (C16:0), stearic (C18:0) and oleic (C18:1n9) acid comprised the greatest proportions of the fatty acids in both the *m. semimembranosus* and 8-9-10-rib cut. On the LE-diet there was no significant difference between the SFA:UFA composition of goat meat and lamb. However, on the HE-diet lamb had a significantly higher SFA:UFA ratio than chevon (*m. semimembranosus*: 0.842 vs. 0.689; 8-9-10-rib cut: 1.407 vs. 0.892). Goat meat could therefore be considered as a healthy food commodity especially among low-income groups or people wishing to consume a low calorie diet.

Key words: fatty acid profile, cholesterol content, diet energy content.

INTRODUCTION

Dietary cholesterol is an important issue of public health because of its relationship with the incidence of atherosclerosis. It is generally accepted that excessive fat consumption above a person's caloric needs is an important risk factor in cardiovascular heart disease, hypertension, stroke, diabetes and obesity. Currently, consumers are especially conscious of their dietary intake of high-fat animal food that contains saturated fats and cholesterol, which, in turn, elevate serum cholesterol (Flynn, Naumann, Nolph, Krause & Ellersieck, 1985). However, a limited consumption of both saturated fatty acids (SFA) and unsaturated fatty acids (UFA) is recommended by the National Cholesterol Educational Program (NCEP)

(1988), while the American Heart Association has recommended 300 mg cholesterol per day for men and 225 mg for women (Krzynowek, 1985). Fat quality affects the appearance, palatability, nutritive value, processability and shelf life of meat and is therefore an important quality determinant of meat (Kempster, Cuthbertson & Harrington, 1982; Casey, Van Niekerk & Spreeth, 1988; Rhee, 1992; Webb, Bosman & Casey, 1994).

Fatty acids are the most important lipid fraction. It has a particular role in the immune function, prevention of inflammation and is an energy source (Wan, Haw & Blackburn, 1989). The degree of saturation of fat, as determined by fatty acid composition, is one of the most important characteristics affecting its quality. Saturated fats solidify easily upon cooling and increase the hardness of the fat, thus affecting the palatability of the meat and consumer acceptability (Casey & Van Niekerk, 1985; Webb *et al.*, 1994). On the other hand the less saturated fats are easily oxidized leading to rancidity, and thereby influencing shelf life (Casey & Van Niekerk, 1985).

The economical aspects of meat production seems to favour the marketing of heavy weight lambs, fattened on high density diets, due to reduced production costs and improved feed efficiency (Casey *et al.*, 1988). However, carcasses from heavy weight lambs are sometimes under valued because of a discolouration, oiliness or lack of firmness of the subcutaneous adipose tissue, associated with a slight shift from saturated to unsaturated fatty acids (Wood, 1984; Cazes, Vallade & Van Quackebeke, 1990).

The quality and composition of ruminant fat may be affected by nutrition, in particular the kind, nature and mode of presentation of cereals or roughages (Casey & Van Niekerk, 1985; Duncan, Ørskov, Fraser & Gordon, 1974; Ørskov, Fraser & Gordon, 1974; Miller, Kunsman & Field, 1980). Pelleting of high-energy diets significantly reduced the incidence of soft fat and improved the overall acceptability of lamb carcasses (Casey & Webb, 1995; Webb, Bosman & Casey, 1997). The reason for this may be that high density diets shorten the grain feeding period and limit the accumulation of displeasing concentrations of unsaturated fatty acids in subcutaneous adipose tissue, which may yield more acceptable carcasses (Casey & Webb, 1995).

It is generally accepted that, in humans, plasma cholesterol concentration is influenced by the fatty acid composition of dietary fat. High dietary levels of long-chain SFA increase plasma cholesterol levels compared with high levels of mono-unsaturated fatty acids (MUFA) and poli-unsaturated fatty acids (PUFA) (Grundy & Denke, 1990). However, not all SFA have equivalent effects. Lauric (C12:0), myristic (C14:0) and palmitic (C16:0) acids raise plasma cholesterol levels (Denke & Grundy, 1992; Sundram, Hayes & Siru, 1994; Tholstrup, Marckmann, Jespersen & Sandrom, 1994; Zock, De Vries & Katan, 1994), whereas stearic acid (C18:0) has no effect (Bonanome & Grundy, 1988; Denke & Grundy, 1992). Bonanome

& Grundy (1988) reported that oleic acid (C18:1n9) seems to decrease blood cholesterol content. According to the health classification of Rhee (1992) the desirable fatty acids (DFA) are the total of all UFA and C18:0.

Goats deposit more gastro-intestinal tract (GIT) fat (which can easily be removed) and less subcutaneous and intramuscular fat compared to sheep (Smith, Carpenter & Shelton, 1978, Van Niekerk & Casey, 1988; Babiker, El Khider & Shafie, 1990; Colomber-Rocher, Kirton, Mecer & Duganzich, 1992). Hence, consumers are interested in goat meat (chevon) as a source of relatively lean meat, especially in developed countries with a high incidence of cardiovascular disease (Naidu, 1996; James & Berry, 1997; Banskalieva, Sahlu & Goetsch, 2000).

The potential of the Boer goat (BG) as a meat-producing animal has been recognized by early researchers such as Owen & Norman (1977) and Casey (1983). However, little is known about the meat quality of goats under intensive conditions.

The South African Mutton merino (MM) was selected as a standard to compare with the BG for this investigation. The MM is a dual-purpose breed, developed to produce a slaughter lamb at an early age. It has a high fertility, good conformation, good feed conversion ratio and adaptability and is therefore popular in feedlot production systems.

Therefore the objectives of this investigation were to determine the effects of diet and days spend in the feedlot on the fatty acid profile and cholesterol content of the meat of BG kids in comparison to MM lambs.

MATERIALS AND METHODS

Thirty-two BG kids and 32 MM lambs were used for this investigation. All the animals were castrated and weaned before entering the feedlot. The average initial body weight of the kids and lambs were 26.23 ± 3.86 kg and 32.72 ± 2.13 kg, respectively. The animals were randomly allocated to four treatment groups of eight animals per species and housed individually in an enclosed but adequately ventilated shed with a slatted floor. The individual pens were built of a material that allowed adjacent animals so see and interact with each other. The study was conducted between October and December 1999 on the experimental farm of the University of Stellenbosch, South Africa. Two pelleted diets were formulated according to the NRC (1985) recommendations for lambs, on an isonitrogenous basis (14.4% crude protein (CP) on a DM basis) to contain either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) calculated metabolisable energy level (Table 1). The animals received the diets and water *ad lib*. After 28 days, 16 BG's and 16 MM's were slaughtered, while the rest of the animals continued in the trial until day 56, when they were slaughtered.

When slaughtered, the animals were first stunned electronically (200V for 10s). After exsanguination the carcasses were hung to bleed. The carcasses were eviscerated using standard procedures and then hung in a cooler (4°C) for 24 hours.

On the right hand side of the carcass, the *longissimus dorsi* rib samples were cut from the 8'th to 10'th thoracic vertebrae and the *m. semimembranosus* was dissected from the left hind leg. The lipids in *m. semimembranosus* were analysed for fatty acid content, while the 8-9-10-rib cuts was analysed for fatty acid and cholesterol content. The fatty acid profile of the two diets fed are presented in Table 2.

Fatty acid methyl esters (FAME) were prepared according to the method of Morrison & Smith (1964). The FAME were analysed with a GLC: Varian Model 3300, equipped with flame ionisation detection and two 30 m fused silica megabore DB-225 columns of 0.53 mm internal diameter (J&W Scientific Folsom, CA). Gas flow rates were: hydrogen, 25 ml/min; air, 250 ml/min; and nitrogen (carrier gas), 5-8 ml/min. Temperature programming was linear at 4°C/min; initial temperature, 160°C; final temperature, 220°C held for 10 min; injector temperature, 240°C; and detector temperature, 250°C. The FAME were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota). Cholesterol content was determined according to the method described by Van Jaarsveld, Smuts, Tichelaar, Kruger and Benadé (2000).

Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1990). The following model was used to determine the presence of the three-way interaction:

$Y_{ijk} = \mu + S_i + D_j + A_k + SD_{ij} + SA_{ik} + DA_{jk} + SDA_{ijk} + e_{ijk}$

Y_{ijk} = Dependent variable of the i'th species of the j'th diet of the k'th slaughter age

μ = Overall mean

S_i = Species effect

D_j = Diet effect

A_k = Slaughter age effect

SD_{ij} = Species-diet interaction

SA_{ik} = Species-slaughter age interaction

DA_{jk} = Diet-slaughter age interaction

SDA_{ijk} = Species-diet-slaughter age interaction

e_{ijk} = Random error of measurement term

The differences between the diets, species and slaughter ages were, where appropriate, tested separately by means of the null hypotheses (H_0), with H_0:$\mu=\mu_0$ and the alternate hypothesis (H_a) being H_a:$\mu\neq\mu_0$. This was done by means of contrast analyses and estimated least square means (± SE). Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$) for diet, species or age.

Table 1. Ingredients and chemical composition of the two diets fed to BG kids and MM lambs

Item	Low energy diet	High energy diet
Ingredients (air dry basis)	**%**	**%**
Wheat Bran	1.50	0.00
Maize Meal	30.00	38.00
Sunflower Oilcake	1.64	4.46
Groundnut Oilcake	3.33	0.00
Limestone	0.07	0.58
Urea	0.70	0.59
Maize Germ[1)]	0.00	9.31
Supermax Premix[2)]	0.00	10.45
Vit/Min Premix[3)]	0.21	0.21
Mono Calcium Phosphate	0.00	0.11
Salt	0.50	0.50
Citrus Ruminant Flavour	0.02	0.02
Ammonium Chloride	0.75	0.75
Taurotec[4)]	0.03	0.03
NaOH Wheat Straw	21.26	15.00
Lucerne Hay	35.00	15.00
Molasses Cuber	5.00	5.00
Chemical composition (DM basis)	**Content**	**Content**
Crude Fat (%)	2.18	5.59
Crude Protein (%)	14.29	14.56
ME (MJ/kg)[5)]	8.90	10.90

[1)]Supplied by Cape Oil (Berkleyroad, Box 16, Maitland)

[2)]Rumen inert fat; supplied by Marine Oil (Division Tiger Food, Mainroad Didovalley, Simons Town)

[3)]A standard mineral (macro and micro) and vitamin supplement formulated by Meadow Feed Mills (Westhovenstr, Box 262, Paarl) accoding to the NRC (1985).

[4)]A growth promoter; supplied by Roche (Wycroftroad, Box 13167, Mowbray)

[5)]Based on the nutritive value of feeds according to laboratory determined values by Meadow Feed Mills

RESULTS AND DISCUSSION

The BG's had significantly less cholesterol (66.77 ± 5.497 mg/100g) in its 8,9,10 rib cut (and therefore presumably in the carcass) than the MM (99.28 ± 5.497 mg/100g). Rowe, Macedo, Visentainer, Souza & Matsushita (1999) reported a cholesterol value of 57.76 mg/100g in the *longissimus dorsi* muscles of drylot lambs (slaughtered when their weights ranged from 29-31 kg). Park, Kouassi & Chin (1991) reported a similar cholesterol value of 57.8 mg/100g for Alphine and Nubian postweaned goat kids' *longissimus dorsi* muscles. However, the USDA (2001 a & b) gives a value of 57.0 mg/100g of edible portion for raw goat meat and 72.0 mg/100g for raw sheep meat, fat trimmed to 6.3 mm.

The reason why the cholesterol values from this investigation are higher than those from the mentioned literature, is that the samples of this investigation consisted not only of muscle, intramuscular and intermuscular fat, but also included subcutaneous fat. This agrees with the results form another part of this investigation where it was found that BGHE56 has significantly less fat in it's 8-9-10-rib cut than the MMHE56 (20.22 vs. 36.85%) (Sheridan, Hoffman & Ferreira, 2001).

The LE-diet (Table 2) had more UFA's than the HE-diet, with oleic acid (C18:1n9) (27.20%) being the most prominent MUFA and linoleic acid (C18:2n6) (36.33%), linolenic acid (C18:3n3) (5.10%) and docosatetraenoic (DTA) (C22:4n6) (2.55%) the most prominent PUFA's. This resulted in the LE diet having a lower SFA:UFA ratio than the HE-diet (0.37 vs. 1.50). Palmitic acid (C16:0) was the most predominant saturated fatty acid in the HE-diet (34.11%), followed by stearic acid (C18:0) (23.70%). As in the LE-diet, oleic acid (C18:1n9) was the most predominant MUFA in the HE-diet (15.51%). The HE-diet had significantly less PUFA than the LE-diet. Linoleic acid (C18:2n6) had the highest concentration in the HE-diet (21.88%). C18:3n3 was the only other PUFA in the HE-diet having a concentration >1% (1.93%).

There was no difference (P>0.05) in fatty acid profile between the animals slaughtered after 28 days and their contemporaries slaughtered after 56 days. Therefore the data was pooled and only diet and species were considered as main effects.

Palmitic (C16:0), stearic (C18:0) and oleic (C18:1n9) acid comprised the greatest proportions of the fatty acids in both the *m. semimembranosus* (Table 3) and 8-9-10-rib cut (Table 4). This agrees with the results of Casey & Van Niekerk (1985) on BG's and Webb, Bosman & Casey (1997) on MM's. Other fatty acids with proportions >1% are the SFA C14:0 (myristic), the MUFA C16:1n7 (palmitoleic) and the PUFA C18:2n6 (linoleic). Arachidonic acid (C20:4n6) was also prominent in the *m. semimembranosus*. Banskalieva, Sahlu & Goetsch (2000), in a review, found that in goat muscle lipids concentrations for C18:1 are between 28 and 50%; 15-31% for C16:0; 6-17% for C18:0 and 4-15% for C18:2. For this investigation only fatty acids with a concentration >1% will be discussed.

Table 2. Fatty acid profile (fatty acids as % of fatty acids identified) of the two diets fed to the BG kids and MM lambs

Fatty acid	Low energy diet	High energy diet
C14:0	0.31	0.19
C16:0	17.84	34.11
C18:0	5.44	23.70
C20:0	1.03	0.86
C22:0	1.17	0.51
C24:0	1.55	0.63
SFA[1)]	27.34	60.00
C16:1n7	0.41	0.00
C18:1n9	27.20	15.61
C20:1n9	0.28	0.16
C24:1n9	0.00	0.04
MUFA[2)]	27.89	15.81
C18:2n6	36.33	21.88
C18:3n3	5.10	1.93
C20:2n6	0.10	0.05
C20:3n3	0.00	0.04
C22:2n6	0.69	0.00
C22:4n6	2.55	0.25
C22:6n3	0.00	0.04
PUFA[3)]	44.77	24.19
SFA:UFA[4)]	0.37	1.50

[1)] Saturated fatty acids
[2)] Mono-unsaturated fatty acids
[3)] Poli-unsaturated fatty acids
[4)] Saturated fatty acids : Unsaturated fatty acids

Myristic acid (C14:0) was higher ($P<0.01$) in the *m. semimembranosus* of MM's than in BG's. However, in both species, animals on the LE-diet had a significantly higher C14:0 concentration than those on the HE-diet. Both the LE- and HE-diet had low C14:0 concentrations (0.31 and 0.19%, respectively), which therefore indicates that the higher C14:0

content of the meat of both the BG's and MM's is the result of hydrogenation and breakdown of long chained (possibly unsaturated) fatty acids. There was no difference between the C16:0 concentrations of BG's and MM's on the LE-diet, but on the HE-diet goats had a lower concentration of palmitic acid than sheep. Since the LE-diet contained significantly less C16:0 than the HE-diet (17.84 vs. 34.1%) and the meat's C16:0 content varied between 22.44% and 25.60% it is reasonable to accept that the animals on the LE-diet synthesized palmitic acid by hydrogenation and breakdown of long chained fatty acids. However, the excess C16:0 in the HE-diet was probably desaturated to palmitoleic acid (C16:1n7) or desaturated and elongated to C18:1n9.

The stearic acid (C18:0) concentration was neither influenced by diet within a species, nor by species within a diet. The same trend that was evident with C16:0, could be seen in the C18:0 concentration, since the LE-diet contained significantly less stearic acid than the HE-diet (5.44 vs. 23.70%). These results indicate that C18:0 too was synthesized in the animals on the LE-diet (probably through hydrogenation of linoleic and/or linolenic acid), while the HE-diet's excess C18:0 was probably desaturated and/or elongated.

In terms of total SFA concentration, diet had no influence within a species, and on the LE-diet there was no significant difference between the SFA concentration of chevon and lamb. However, on the HE-diet, MM's had a higher ($P<0.001$) SFA concentration in their *m. semimembranosus* than BG's.

Both the C16:1n7 (palmitoleic acid) and C18:1n9 (oleic acid) concentration of BGLE's meat did not differ ($P>0.05$) from that of MMLE, but on the HE-diet, BG's had a higher concentration than MM's. Goats had the highest ($P<0.05$) C16:1n7 concentration on the HE-diet, while sheep had the highest ($P<0.05$) C18:1n9 concentration on the LE diet. There was no significant difference between the MUFA concentration of goats on the LE-diet and those on the HE-diet, while MMLE had higher MUFA concentrations than MMHE. Thus, the MUFA concentration of the meat of the two species did not differ significantly from one another on the LE-diet, while on the HE-diet, goats had a significantly higher MUFA-concentration than sheep.

The PUFA C18:2n6 (linoleic acid) was significantly higher in the BGLE than in the MMLE, while there was no difference ($P<0.05$) between MMHE and BGHE. There was also no significant difference between goats on a LE-diet and those on the HE-diet, while sheep on the HE-diet had a higher C18:2n6 concentration than those on the LE-diet. The excess C18:2n6 in the two diets, which was not incorporated in the meat, was probably hydronated to C18:1n9. Linolenic (C18:3n6) and arachidonic acid (C20:4n6) can also be synthesized in the body if linoleic acid is in adequate supply (Gurr, 1971).

Table 3. Fatty acid profile of the *m. semimembranosus* of the BG kids and MM lambs (% of identified fatty acids)

Fatty acid	BGLE[1]	BGHE[2]	MMLE[1]	MMHE[2]	SE
C14:0	1.84^{b}	1.31^{a}	2.70^{c}	2.24^{b}	0.162
C16:0	24.06^{b}	22.44^{a}	24.57^{bc}	25.60^{c}	0.498
C18:0	15.44^{a}	16.63^{ab}	16.28^{ab}	17.11^{b}	0.477
C20:0	0.41^{b}	0.21^{a}	0.20^{a}	0.13^{a}	0.049
C22:0	0.16^{a}	0.03^{a}	0.09^{a}	0.16^{a}	0.062
C24:0	0.07^{a}	0.03^{a}	0.07^{a}	0.23^{a}	0.093
SFA[3]	41.98^{ac}	40.65^{a}	43.92^{bc}	45.47^{b}	0.733
C16:1n7	1.38^{b}	2.06^{a}	1.56^{b}	1.32^{b}	0.089
C18:1n9	45.80^{ab}	47.06^{a}	46.05^{a}	43.19^{b}	0.968
C20:1n9	0.11^{b}	0.06^{a}	0.14^{b}	0.13^{b}	0.013
C24:1n9	0.12^{a}	0.06^{a}	0.04^{a}	0.26^{a}	0.121
MUFA[4]	47.41^{ab}	49.24^{a}	47.80^{a}	44.90^{b}	0.942
C18:2n6	5.10^{a}	5.52^{a}	3.96^{b}	5.36^{a}	0.336
C18:3n6	0.05^{b}	0.17^{a}	0.07^{b}	0.05^{b}	0.018
C18:3n3	1.11^{b}	0.46^{a}	1.01^{bc}	0.79^{c}	0.092
C20:2n6	0.17^{b}	0.03^{a}	0.48^{c}	0.14^{ab}	0.046
C20:3n6	0.02^{a}	0.00^{a}	0.13^{b}	0.01^{a}	0.035
C20:4n6	2.53^{a}	2.20^{a}	1.14^{b}	1.26^{b}	0.130
C20:3n3	0.02^{a}	0.00^{a}	0.13^{b}	0.01^{a}	0.035
C20:5n3	0.44^{a}	0.42^{a}	0.40^{a}	0.41^{a}	0.053
C22:2n6	0.06^{a}	0.11^{a}	0.07^{a}	0.05^{a}	0.037
C22:4n6	0.23^{a}	0.14^{ab}	0.08^{b}	0.14^{ab}	0.037
C22:3n3	0.02^{a}	0.00^{a}	0.06^{ab}	0.18^{b}	0.054
C22:5n3	0.69^{a}	0.66^{a}	0.44^{a}	0.94^{a}	0.232
C22:6n3	0.03^{b}	0.14^{a}	0.23^{a}	0.23^{a}	0.037
PUFA[5]	10.61^{a}	10.11^{a}	8.28^{b}	9.63^{ab}	0.533
UFA[6]	58.02^{ac}	59.35^{a}	56.08^{bc}	54.53^{b}	0.733
SFA:UFA	0.725^{ac}	0.689^{a}	0.788^{bc}	0.842^{b}	0.0235
(C18:0+C18:1):C16:0	2.56^{b}	2.87^{a}	2.55^{b}	2.39^{b}	0.081
DFA[7]	73.46^{b}	75.98^{a}	72.36^{bc}	71.64^{c}	0.605

[1]BGLE/MMLE: Low energy diet, fed to Boer goats or Mutton merinos, [3]BGHE/MMHE: High energy diet, fed to Boer goats or Mutton merinos, [3]Saturated fatty acids, [4]Mono-unsaturated fatty acids, [5]Poli-unsaturated fatty acids, [6]Unsaturated fatty acids, [7]Desirable fatty acids, [a,b,c] Means in the same row with different superscripts differ ($P<0.05$)

BGLE had a significantly higher C18:3n3 concentration than BGHE, while the concentration did not differ (P>0.05) between MMLE and MMHE. The result is that the C18:3n3 concentration of goats and sheep's *m. semimembranosus* did not differ significantly from one another, but on the HE-diet goats had a significantly lower concentration than sheep. Dietary α-linolenic acid (C18:3n3) is a good example of a fatty acid not readily incorporated into tissue lipids. It is mainly oxidised to CO_2 and water (Aeberhard, Corbo & Menkes, 1978). Some is converted via desaturation and elongation to eicosapentaenoic (EPA; C20:5n3), docosapentaenoic (DPA; C22:5n3) or C22:6n3, but only a small portion of the α-linolenic acid enters the enzymatic pathways for catabolism (De Gomez-Dumm & Brenner, 1975; Sprecher & Lee, 1975). Mammalian cells are not capable of introducing double bonds beyond carbon atom 9. As a result, it is not possible for mammalian tissues to synthesize either linoleic acid (C18:2n6) or linolenic acid (C18:3) and these fatty acids have to be provided in the diet.

On both the LE- and HE-diets goats had a higher C20:4n6 concentration than sheep. This agrees with the findings of Banskalieva *et al.* (2000) who concluded that pork, beef and chevon have higher C20:4n6 concentrations than lamb. Within a species, diet had no effect on the C20:4n6 concentration in our investigation.

Similarly, within a species, diet also had no influence (P>0.05) on the total PUFA concentration, and on the HE-diet the concentration was not significantly different between BG's and MM's, but on the LE-diet goats had a higher (P<0.01) PUFA concentration than sheep. This agrees with the fact that after both 28 and 56 days MM's on the LE-diet had significantly more fat in their *m. semimembranosus* than the BG's (Sheridan *et al.*, 2001). With a decrease in fat, the proportion of cell walls (and thus the PUFA) increases.

Within a species, diet had no influence on the *m. semimembranosus'* UFA concentration or SFA:UFA ratio. Also, on the LE-diet there was no difference (P>0.05) between the UFA concentration and SFA:UFA ratio of goats and sheep, but on the HE-diet goats had a significantly higher UFA concentration and thus a lower SFA:UFA ratio.

BGHE had the highest DFA (desirable fatty acids are the sum of UFA and C18:0, according to Rhee, 1992) content and (C18:0+C18:1):C16:0 ratio (75.98% and 2.87, respectively), followed by BGLE (73.46% and 2.56), MMLE (72.36% and 2.55) and MMHE (71.64% and 2.39).

Present data differs from Rhee, Waldron, Ziprin & Rhee's (2000) fatty acid profile of young Boer x Spanish goats' *m. semimembranosus.* They found range goats to have a SFA:UFA ration of 0.73, while grain-fed goats had a ration of 0.54.

The C14:0 concentration of the goats' 8-9-10-rib cuts (Table 4) did not differ significantly between diets, while MMHE had a lower concentration than MMLE. On the LE-diet goats had

Table 4. Fatty acid profile of the 8-9-10-rib cut of the BG kids and MM lambs (% of identified fatty acids)

Fatty acid	BGLE[1)]	BGHE[2)]	MMLE[1)]	MMHE[2)]	SE
C14:0	1.95[a]	1.35[a]	2.76[c]	1.75[a]	0.255
C16:0	23.06[ac]	24.83[a]	20.62[c]	28.89[b]	1.006
C18:0	20.19[a]	20.46[a]	26.10[b]	27.04[b]	0.924
C20:0	0.34[a]	0.33[a]	0.30[a]	0.59[b]	0.030
C22:0	0.04[b]	0.01[a]	0.05[b]	0.02[c]	0.004
C24:0	0.03[a]	0.03[a]	0.09[a]	0.06[a]	0.031
SFA[3)]	45.59[a]	47.01[ac]	49.93[c]	58.31[b]	1.048
C16:1n7	1.99[ac]	2.21[a]	1.61[c]	1.20[b]	0.141
C18:1n9	48.89[a]	46.91[ac]	44.19[c]	37.62[b]	1.058
C20:1n9	0.13[ab]	0.12[ab]	0.15[b]	0.09[a]	0.015
C24:1n9	0.05[a]	0.02[a]	0.12[a]	0.01[a]	0.047
MUFA[4)]	51.06[a]	49.26[a]	46.07[c]	38.92[b]	1.080
C18:2n6	2.21[a]	2.51[a]	2.44[a]	2.12[a]	0.178
C18:3n6	0.13[a]	0.17[a]	0.04[b]	0.06[b]	0.011
C18:3n3	0.37[b]	0.27[a]	0.71[c]	0.29[a]	0.026
C20:2n6	0.04[a]	0.03[a]	0.14[b]	0.02[a]	0.019
C20:3n6	0.05[a]	0.06[a]	0.04[ab]	0.02[b]	0.007
C20:4n6	0.29[a]	0.31[a]	0.19[c]	0.09[b]	0.020
C20:3n3	0.01[a]	0.00[a]	0.03[b]	0.00[a]	0.005
C20:5n3	0.04[a]	0.04[a]	0.04[a]	0.03[a]	0.006
C22:2n6	0.02[a]	0.02[a]	0.08[a]	0.02[a]	0.027
C22:4n6	0.06[ab]	0.06[ab]	0.10[b]	0.01[a]	0.022
C22:3n3	0.00[a]	0.00[a]	0.06[b]	0.00[a]	0.006
C22:5n3	0.15[a]	0.17[a]	0.11[c]	0.06[b]	0.014
C22:6n3	0.06[a]	0.09[a]	0.03[ab]	0.02[b]	0.014
PUFA[5)]	3.35[ab]	3.73[ac]	4.00[c]	2.77[b]	0.217
UFA[6)]	54.41[a]	52.99[ac]	50.07[c]	41.69[b]	1.048
SFA:UFA	0.845[a]	0.892[a]	1.030[c]	1.407[b]	0.0431
(C18:0+C18:1):C16:0	3.04[a]	2.74[a]	4.45[b]	2.26[a]	0.427
DFA[7)]	74.60[a]	73.45[a]	76.17[a]	68.73[b]	1.176

[1)]BGLE/MMLE: Low energy diet, fed to Boer goats or Mutton merinos, [3)]BGHE/MMHE: High energy diet, fed to Boer goats or Mutton merinos, [3)]Saturated fatty acids, [4)]Mono-unsaturated fatty acids, [5)]Poli-unsaturated fatty acids, [6)]Unsaturated fatty acids, [7)]Desirable fatty acids, [a,b,c] Means in the same row with different superscripts differ (P<0.05) a lower concentration ($P<0.01$) of C14:0 than sheep, but on the HE-diet no difference was evident.

The opposite was noted for the C16:0 concentration with goats having a significantly lower concentration on the HE-diet than sheep, while no difference occurred on the LE-diet. BGHE's C16:0 concentration did not differ significantly form BGLE, but MMHE had a significantly higher concentration than MMLE. The reason for these phenomena probably lies in the fact that the MM's were significantly fatter than the BG's (Sheridan, Hoffman & Ferreira, 2001). An increase in subcutaneous fat will increase the SFA-content of the meat.

Within a species, diet had no influence ($P>0.05$) on the C18:0 concentration of the 8-9-10-rib cut. Species had an influence, with goats having a significantly lower C18:0 concentration than sheep on both diets, probably again because the sheep were fatter.

Goats had a lower SFA concentration than the sheep on both the HE- and LE-diet. However, total SFA concentration of BGHE did not differ ($P>0.05$) from that of BGLE, but MMHE had a significantly higher SFA concentration than MMLE.

The palmitoleic acid and oleic acid concentration of BGHE were not significantly different from BGLE, but MMLE had both a higher ($P<0.05$) C16:n7 and C18:1n9 concentration than MMHE. On the LE-diet there was no significant difference between the two species' C16:1n7 concentration, but on the HE-diet goats had a significantly higher concentration than the sheep. On both diets goats had a higher ($P<0.0001$) C18:1n9 concentration. Both Gaili & Ali (1985) and Banskalieva *et al.* (2000) found that fattened goats deposit more C18:1 subcutaneously than fattened sheep.

BG's had a significantly higher total MUFA concentration in their 8-9-10-rib cuts than MM's on both diets. While the MMHE had a significantly lower MUFA concentration than the MMLE, there was no difference ($P>0.05$) between BGHE and BGLE. The reason is probably because the goats were not as fat as the sheep and therefore the relationship between cell wall and cell content of the adipose tissue were greater in the goats. Cell walls comprise mainly UFA's which explains the higher MUFA concentration of the chevon.

The linoleic acid concentration of the 8-9-10-rib cut was neither influenced by diet, nor by species. There was no significant difference between the PUFA concentration of goats on the LE-diet and those on the HE-diet, but MMHE had a significantly lower PUFA concentration than MMLE. Reed (1980) concluded that along with other PUFA, linoleic acid helps reduce serum cholesterol. The fact that the BGHE had a significantly higher PUFA-concentration than the MMHE, may therefore have had an influence on the fact that the goat's 8-9-10-rib cut had significantly less cholesterol.

On both diets total UFA concentration of the 8-9-10-rib cut was higher ($P<0.005$) in BG's than in MM's. There was no significant difference between the UFA concentration of BGHE and

BGLE, but the MM's on the LE-diet had a significantly higher concentration than those on the HE-diet. Therefore, on both diets goats had a lower ($P<0.005$) SFA:UFA ratio than sheep. There was no difference ($P>0.05$) between the SFA:UFA ratio of BGLE and BGHE, but MMLE had a significantly lower ratio than MMHE.

The DFA of goats were not significantly different from that of sheep on the LE-diet, while on the HE-diet goats had a higher concentration ($P<0.01$) DFA than sheep. There was no significant difference between BGLE and BGHE's DFA (74.60 vs. 73.45%, respectively), but MM's had a higher ($P<0.0001$) concentration on the LE-diet than on the HE-diet (76.17% vs. 68.73%, respectively). In a review article Banskalieva *et al.* (2000) stated that the DFA of goat muscles range between 71.67 and 79.79% and that of sheep/lamb between 63.97 and 71.50%.

CONCLUSION

The BG had significantly lower levels of cholesterol in its 8-9-10-rib cut (and therefore presumably in the carcass) than the MM. On the HE-diet the MM's *m. semimembranosus* had more ($P<0.01$) SFA, while the BG's had significantly more UFA (PUFA+MUFA). However, on the LE-diet there was no significant difference between the SFA:UFA ratio of BG's and MM's. BGHE had a significantly higher (and thus more desirable) (C18:0+C18:1):C16:0 ratio in its *m. semimembranosus*, as well as more DFA than the MMHE. The tested diets do not seem to alter the profile of the BG's 8-9-10-rib cut's fatty acids. However, the MMHE had significantly higher proportions of SFA than the MMLE and thus a significantly higher SFA:UFA ratio. On both diets the goats had a significantly lower SFA:UFA ratio than the sheep. Thus, on a high energy feedlot diet goats have a significantly lower carcass cholesterol content and SFA:UFA ratio than sheep. Goat meat could therefore be considered as a healthy food commodity especially among low-income groups or people wishing to consume a diet low in cholesterol, SFA and calories.

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SENSORY MEAT EVALUATION OF BOER GOAT KIDS AND SA MUTTON MERINO LAMBS RECEIVING EITHER A LOW OR A HIGH ENERGY FEEDLOT DIET

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ABSTRACT

The meat palatability, water holding capacity, colour and shear force values of 32 Boer goat (BG) kids and 32 South African Mutton merino (MM) lambs were investigated. Two pelleted diets (fed to 16 animals/species) with either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) metabolisable energy level were fed to the animals for either 28 or 56 days. Thereafter the animals were slaughtered, the meat cooked and presented to a trained sensory panel. Organoleptically, a difference between chevon and lamb was noted. Each one had a specific species flavour, which is not influenced by energy level of the diet. BG meat was perceived to be stringier than that of the MM, but there was no significant difference in Warner-Bratzler shear force values. Tenderness declined with age in both species and there was also a tendency for goat meat to be less juicy than lamb. Chevon had a more pronounced aftertaste than lamb. No objective difference could be distinguished between the colour of the cooked chevon and lamb, but there was a tendency for fresh lamb to have a higher a*-value (redness) than chevon. Although diet did no influence drip loss, drip loss increased with an increase in slaughter age. Only after 56 days did the MM's *m. semimembranosus* have a significantly higher drip loss than the BG's (LE: 4.84 vs. 3.43%; HE: 4.72 vs. 3.32%). In the *m. semimembranosus* of both species cooking loss increased with an increase in slaughter age. It can be concluded that goat meat compares favourably with lamb in terms of water holding capacity, colour and shear force values. If goats are finished in the feedlot, it can be done on a LE-diet, since diet does not influences any of the mentioned characteristics. This may render a direct economic advantage for BG feedlot finishing.

Key words: water holding capacity, palatability, tenderness, diet energy content.

INTRODUCTION

Young goat meat is characterised by a low intramuscular and subcutaneous fat content (Babiker, El Khider & Shafie, 1990; Johnson, McGoven, Nurse & Anous, 1995, Sheridan, Hoffman & Ferreira, 2001). Consumers value low-fat, high quality products and therefore there is potential development for the goat meat market (Carlucci, Girolami, Napolitano & Monteleone, 1998). Besides odour and taste, colour, texture, tenderness and juiciness also influence acceptability of meat. According to Risvik (1994) consumers generally prefer tender and juicy meat. However, the most important property is the appearance, because this strongly influences the initial decision of the customer to purchase or reject the product.

As goats are selective feeders (Provenza, 1995), the diets in this investigation were pelleted. Casey & Webb (1995) and Webb, Bosman & Casey (1997) reported that the pelleting of high density diets may improve the composition and quality of ovine fat and thus both carcass and meat quality.

The potential of the Boer goat (BG) as a meat-producing animal has been recognised by early researchers such as Owen & Norman (1977) and Casey (1983). However, little is known about the performance of goats under intensive/feedlot conditions. The South African Mutton merino (MM) was selected as a standard to compare with the BG in this investigation. The MM is a dual-purpose breed, developed to produce a slaughter lamb at an early age. It has a high fertility, good conformation, good feed conversion ratio and adaptability and is therefore popular in feedlot production systems.

Although numerous studies have been performed to compare the palatability of goat and sheep meat, little is known about the organoleptic characteristics of goat meat (chevon) when the animals are finished under feedlot conditions. Therefore the objectives of this investigation were to determine the effects of diet, species and days spent in the feedlot on (1) cooking loss, (2) drip loss, (3) colour, (4) shear force values and (5) organoleptic characteristics.

MATERIALS AND METHODS

Thirty-two BG kids and 32 MM lambs were used for this study. All the animals were castrated and weaned before entering the feedlot. The average initial body weight of the kids and lambs were 26.23 ± 3.86 kg and 32.72 ± 2.13 kg, respectively. The animals were randomly allocated to four treatment groups of eight animals per species and housed individually in an enclosed but adequately ventilated shed with a slatted floor. The individual pens were built of a material that allowed adjacent animals so see and interact with each other. The study was conducted between October and December 1999 on the experimental farm of the University of Stellenbosch, South Africa. Two pelleted diets were formulated according to the NRC (1985) recommendations for lambs, on an isonitrogenous basis (14.4% crude protein (CP) on a DM-basis) to contain either a low (LE, 8.9 MJ/kg DM) or a high (HE, 10.9 MJ/kg DM) calculated metabolisable energy level. The animals received the diets and water *ad lib*. The animals were also weighed weekly.

After 28 days, 16 BG's and 16 MM's were slaughtered, while the rest of the animals, continued in the trial until day 56 when they were slaughtered. When slaughtered, the animals were first stunned electronically (200V for 10s). After they were exsanguinated, the carcasses were hung to bleed. No electrical stimulation of the carcasses were applied. The carcasses were eviscerated using standard procedures and hung in a cooler (4°C) for 24 hours.

On the right hand side of the carcass, the *m. longissimus dorsi* samples were cut from the 8'th to 10'th thoracic vertebrae (rib cuts) for chemical analyses and colour measurement. In the chemical analysis of the 8-9-10-rib cuts bone, fat and meat was included. Colour was measured using a hand held Gardner Colorimeter to determine, L*, a* and b*-value, with L* indicating brightness, a* the red-green range and b* the blue-yellow range. Fresh meat colour was determined on a portion of the *m. longissimus* after blooming for 30 minutes. Two additional 1.5 cm back chops were cut, for determination of cooking loss and drip loss. For drip loss determination meat samples of approximately 70 g were weighed immediately after being cut from the carcass. The samples were placed in netting and suspended in an inflated bag. After a storage period of 24 hours at 4°C, samples were weighed again and drip loss were expressed as a percentage of the initial weight. For cooking loss determination samples were freshly cut and weighed (initial weight). Individual slices of approximately 70 g (in thin-walled plastic bags) were placed in a water-bath at 75°C. After one hour the samples were removed from the water-bath and cooled in cold water. The meat was removed from the bag, blotted dry, weighed and cooking loss was expressed as a percentage of the initial sample weight (Honikel, 1998).

The *m. semimembranosus* was dissected from the left hind leg for chemical analysis. Two sub-samples (1.5 cm thick) were removed for determination of cooking loss, drip loss and colour determination. The right hind leg of the animals slaughtered after 56 days were vacuum packed and stored at -13°C for sensory evaluation.

The cooking loss samples were also used to determine shear force values. Toughness was measured as the maximum force (kg/cm^2) required to shear a 1.27cm diameter cylindrical core of cooked meat perpendicular to the grain, at a crosshead speed of 200 mm/min. The shear force measurements were generated with a Warner-Bratzler shear attachment, fitted to an Instron Universal Testing machine. A higher reading indicated greater shear force and therefore tougher meat.

For the sensory analysis, the right hind legs were defrosted at 6°C for a period of 48h. The meat was roasted in two conventional electric Defy 835 ovens connected to a computerized-temperature control system. The meat was roasted in plastic oven bags on a rack in a roasting oven pan. No salt was added to the meat. A thermocouple was inserted in the center of each leg and the meat was roasted to an internal temperature of 72°C in a preheated oven at 180°C. Thereafter the *m. gracilis* muscle was dissected, cut into 1x1x1 cm samples and offered to the panelists.

A triangular test was used in order to ascertain if people could detect a difference between lamb and goat meat, within a diet. Assessors received three 1X1X1 cm samples of which two were from the same species and one was "odd" (e.g. 2XHEMM, 1XHEBG or 1XLEMM, 2XLEBG). Thereafter an eight-member trained descriptive attribute panel was used to evaluate palatability attributes of the meat. The first two sessions were used to develop the profile. For each session, assessors were offered four different meat samples from the animals in the trial and the attributes individually recorded. After each session assessors discussed attributes. After the second session the assessors agreed on an eight attribute profile of appearance, flavour and texture (Table 1). Heated BG kidney fat, Saanen milk and caproic acid were used in the training sessions to establish the strong odour and sour taste typical of goat meat. After a formal training session for scale use, attributes were rated on the basis of 100 mm unstructured lines with anchor points at each end (0: minimum and 100: maximum). Scores were the distance (mm) from the left anchor point. The main trial consisted of six sessions. In each session four samples (five cubes from each of the four treatments) were placed in random order and assessed. Distractions to panelists were reduced by using booths that were illuminated with red light to minimize bias introduced by possible colour differences. Colour was assessed on a different set of samples in natural light. Cream crackers and water were used by the panelists to freshen their mouths between samples.

Analyses of variance were performed on all the variables measured using the General Linear Models (GLM) procedure of SAS (1990). The following model was used to determine the presence of the three way interaction:

$Y_{ijk} = \mu + S_i + D_j + A_k + SD_{ij} + SA_{ik} + DA_{jk} + SDA_{ijk} + e_{ijk}$

Y_{ijk} = Dependent variable of the i'th species of the j'th diet of the k'th slaughter age

μ = Overall mean

S_i = Species effect

D_j = Diet effect

A_k = Slaughter age effect

SD_{ij} = Species-diet interaction

SA_{ik} = Species-slaughter age interaction

DA_{jk} = Diet-slaughter age interaction

SDA_{ijk} = Species-diet-slaughter age interaction

e_{ijk} = Random error of measurement term

The differences between the diets, species and slaughter ages were, where appropriate, tested separately by means of the null hypotheses (H_0), with H_0:$\mu=\mu_0$ and the alternate hypothesis (H_a) being H_a:$\mu \neq \mu_0$. This was done by means of contrast analyses and estimated least square means (± SE). Differences between the variables were accepted as being significant if the probability of rejection of H_0 was less than 5% ($P<0.05$) for diet, species or age.

Table 1. Attributes of meat quality used for sensory evaluation

Attribute	Definition
Flavour	
Goatiness	Strong odour and sour taste associated with caproic acid 0 = not goaty; 100 = goaty
Muttoniness	Those characteristics which suggest to you in some way the muttony nature of the sample 0 = not muttony; 100 = muttony
Aftertaste of juice	0 = not pronounced; 100 = pronounced
Texture	
Tenderness	tender = low force needed to chew the product tenderness = force required to compress the sample of meat between molar teeth on the first bite 0 = tough; 100 = tender
Stringiness	stringy = fibres perceived during mastication 0 = not stringy; 100 = stringy
Juiciness	juicy = water perceived during the mastication juiciness = degree/amount of moisture inside the sample upon chewing 0 = dry; 100 = juicy
Appearance	
Grey	0 = light grey; 100 = dark grey
Pink	0 = light pink; 100 = dark pink

The results from the triangular test were analysed according to the method of Roessler, Pangborn, Sidel & Stone (1979). For the results of the line scale sensory evaluation, analysis of variance was performed on the variables measured using the General Linear Models (GLM) procedure of SAS (1990). The sensory analysis experiment consisted of four treatment combinations, each replicated six times by eight panel members in a completely randomised design. The treatment combinations involved a 1x2x2 factorial array arising from the combination of one cooking method (roasting), two species (BG's and MM's) and two diets

(HE and LE). An effect with probability smaller that 5% ($P<0.05$) was considered as significant.

RESULTS AND DISCUSSION

The objective colour parameters of the fresh meat are presented in Table 2. Within a species, diet did not influence any of the colour parameters. In the group of animals that were slaughtered after 28 days, the chevon had a significantly lighter colour (higher L*) than lamb in both the *m. semimembranosus* and the 8-9-10-rib cut. However, in the 56 day group, there was neither a difference in brightness of the *m. semimembranosus*, nor in the 8-9-10- rib cut of the BG and MM meat.

With the exception of MMLE56, which had a redder (higher a*-value) colour than the BGLE56, redness was not influenced by species, diet or days spent in the feedlot. In the 8-9-10- rib cut the a*-value was only influenced by species, with the goat meat being significantly less red than the lamb. In addition, diet did not influence the yellowness (b*-value) of the meat. The b*-value was only influenced in the lamb with an increase in slaughter age, with the 56 day group being significantly more yellow. Species only had an influence on the 8-9-10-rib cut of the 56-day group of animals. The goat meat was significantly less yellow than the lamb. These results contradict those of Babiker *et al.* (1990) who found that fresh desert goat meat was lighter and more red and yellow than desert lamb. These authors concluded that the increased concentration of sarcoplasmic proteins and the expected decrease of muscle myoglobin as intramuscular fat increased might be implicated in muscle colour differences between the two species.

During the triangular tests the "odd" HE-diet sample was correctly identified 26 times and the "odd" LE-diet sample, 27 times. Twenty-four correct identifications indicate a difference with a significance of 0.01; 25 indicates $P=0.005$ and 27 indicates $P=0.001$. Therefore, the triangular test indicated that people could tell the difference between goat meat and lamb on both the LE diet ($P=0.001$) and the HE diet ($P=0.005$).

The definitions of the organoleptic attributes that were evaluated are depicted in Table 1 and the results of the line scale in Table 3. Within a species, there was no significant difference in flavour between the meat of animals on the high or low energy diet. However, the goat meat had a more ($P<0.05$) "goaty" flavour, while the lamb was more "muttony." In contrast to our data, Gaili, Ghanem & Mukhtar (1972) found no species differences in flavour of lamb and goat meat. The presence of 4-methyloctanoic (hircinoic) acid, in addition to other factors, contributes to the distinctive flavour in sheep and goat meat (Wong, Johnson, & Nixon, 1975). As with flavour, diet did not influence tenderness or stringiness within species, but the goat meat was perceived to be significantly less tender and more stringy than the lamb. Our data

Table 2. Colour parameters of the fresh meat of BG kids and MM lambs receiving either a low or a high energy diet for 28 or 56 days (mean ± SE)

	BGLE28[1)] (n=8)	BGHE28[2)] (n=8)	MMLE28[3)] (n=8)	MMHE28[4)] (n=8)	BGLE56[1)] (n=8)	BGHE56[2)] (n=8)	MMLE56[3)] (n=8)	MMHE56[4)] (n=8)
m. semimembranosus								
L*	37.59[ac] ± 0.906	38.92[a] ± 0.906	34.49[b] ± 0.906	34.69[b] ± 0.906	38.41[ac] ± 0.906	37.54[ac] ± 0.906	37.41[ac] ± 0.906	35.97[bc] ± 0.906
a*	12.16[a] ± 0.312	12.12[a] ± 0.312	12.21[a] ± 0.312	12.83[abc] ± 0.312	12.21[a] ± 0.312	12.43[ab] ± 0.312	13.37[c] ± 0.312	13.18[bc] ± 0.312
b*	8.49[ac] ± 0.380	9.06[a] ± 0.380	7.34[c] ± 0.380	8.31[ac] ± 0.380	9.15[ab] ± 0.380	8.80[a] ± 0.380	8.89[a] ± 0.380	10.19[b] ± 0.380
8-9-10-Rib cut								
L*	43.13[a] ± 1.039	42.10[a] ± 1.039	38.96[c] ± 1.039	38.69[c] ± 1.039	40.46[ac] ± 1.039	40.24[abc] ± 1.039	37.89[c] ± 1.039	38.56[c] ± 1.039
a*	10.15[b] ± 0.373	10.52[ab] ± 0.373	12.05[ef] ± 0.373	11.65[cef] ± 0.373	10.79[abc] ± 0.373	11.27[ace] ± 0.373	13.10[def] ± 0.373	12.57[f] ± 0.373
b*	9.13[bd] ± 0.35	9.80[abd] ± 0.351	9.03[d] ± 0.351	9.64[abd] ± 0.351	10.04[ab] ± 0.351	10.18[a] ± 0.351	11.25[c] ± 0.351	11.50[c] ± 0.351

[1)]BGLE28/56: Low Energy diet, fed to Boer goats for 28/56 days
[2)]BGHE28/56: High Energy diet, fed to Boer goats for 28/56 days
[3)]MMLE28/56: Low Energy diet, fed to Mutton merinos for 28/56 days
[4)]MMHE28/56: High Energy diet, fed to Mutton merinos for 28/56 days
[a,b,c] Means in the same row with different superscripts differ ($P<0.05$)
L* = Lightness; a* = Redness; b* = Yellowness

agrees with that of Field, Williams, Ferrell, Crouse & Kunsman (1978) who concluded that diet has no significant effect on tenderness of ram lamb meat.

However, this is in contrast with Crouse, Field, Chant, Ferrell, Smith & Harrison (1978) who found mutton from a low energy diet (9.12 MJ ME/kg DM) to be inferior in tenderness (P<0.05) to mutton from a high energy diet (11.72 MJ ME/kg DM). There is an indication that goat meat may be tougher than sheep meat from animals of similar age (Kirton, 1970; Smith, Pike & Carpenter, 1974). However, Naudé & Hofmeyr (1981) proposed that intrinsic differences in muscle tenderness between sheep and goats are unlikely, and that pre-slaughter animal treatment and post-slaughter carcass treatment are probably more important determinants of tenderness. In particular, the relatively low subcutaneous fat cover of goats can permit rapid cooling and consequent cold shortening of muscles.

Table 3. Means of analytical sensory meat evaluation (mean ± SE) of BG kids and MM lambs receiving either a low or a high energy feedlot diet for 56 days

ATTRIBUTE	BGLE (n=6)	BGHE (n=6)	MMLE (n=6)	MMHE (n=6)
Goatiness	31.8^{a} ± 4.64	26.4^{a} ± 4.81	13.7^{b} ± 3.79	7.8^{b} ±2.62
Muttoniness	61.3^{a} ± 4.43	65.8^{a} ± 4.45	78.6^{b} ± 3.90	83.0^{b} ± 3.45
Tenderness	50.7^{a} ± 4.46	48.5^{a} ± 4.01	81.4^{b} ± 4.12	$85.0b^{b}$ ± 3.81
Stringiness	47.7^{a} ± 4.24	48.6^{a} ± 4.72	15.3^{b} ± 3.29	15.2^{b} ± 3.49
Juiciness	49.8^{a} ± 4.05	47.4^{a} ± 3.58	58.5^{ab} ± 4.28	66.6^{b} ± 4.76
Aftertaste of juice	42.9^{a} ± 5.18	33.1^{ab} ± 4.18	27.6^{bc} ± 4.59	18.6^{c} ± 3.91
Colour: Grey	45.1^{a} ± 5.41	58.5^{bc} ± 4.62	64.3^{b} ± 4.65	51.9^{ab} ± 5.39
Colour: Pink	44.8^{a} ± 5.58	37.5^{ab} ± 4.45	29.5^{b} ± 4.22	39.0^{ab} ± 5.19

[1)]BGLE: Low Energy diet, fed to Boer goats
[2)]BGHE: High Energy diet, fed to Boer goats
[3)]MMLE: Low Energy diet, fed to Mutton merinos
[4)]MMHE: High Energy diet, fed to Mutton merinos
[a,b,c] Means in the same row with different superscripts differ (P<0.05)

Juiciness was not influenced by diet within a species, but there was a tendency for lamb to be juicier than goat meat. There was also a tendency for sheep to be fatter than goats (Sheridan *et al.*, 2001) and fatness contributes largely to juiciness and flavour. Field *et al.* (1978) also found that diet had no effect on the juiciness of ram lamb meat. In this investigation diet did not influence the aftertaste of the juice within a species, but on both diets the chevon had a more pronounced aftertaste than the lamb.

Therefore it can be concluded that within a species, diet had no significant influence on the sensory evaluation of the meat, but that there are definite differences in terms of flavour and texture between the meat from BG kids and MM lambs raised under feedlot conditions. This is in contrast with the data of Babiker *et al.* (1990) who found no significant differences in the subjective evaluation of juiciness, tenderness and overall acceptability of goat and sheep meat. In our investigation only flavour was significantly lower in goat meat than in lamb, possibly due to fatness code. The sensory panel found differences in the assessment of the colour of cooked meat (Table 3). However, when colour was determined with the Gardner Colorimeter, no difference could be found in terms of the L*, a* and b*-values of the cooked meat (Table 4).

Table 4. Colour parameters of the cooked goat and sheep meat used for the sensory evaluation as determined by the Colorimeter (mean ± SE)

	BGLE (n=6)	BGHE (n=6)	MMLE (n=6)	MMHE (n=6)
L*	55.91 ± 1.496	55.61 ± 1.496	53.54 ± 1.496	54.49 ± 1.496
a*	16.33 ± 0.368	15.82 ± 0.368	16.50 ± 0.368	16.28 ± 0.368
b*	68.69 ± 2.555	70.19 ± 2.555	65.85 ± 2.555	69.39 ± 2.555

[1)]BGLE: Low Energy diet, fed to Boer goats
[2)]BGHE: High Energy diet, fed to Boer goats
[3)]MMLE: Low Energy diet, fed to Mutton merinos
[4)]MMHE: High Energy diet, fed to Mutton merinos
L* = Lightness; a* = Redness; b* = Yellowness

Table 5 shows the drip loss (%), cooking loss (%) and shear force values (kg/cm^2) of both *the m. semimembranosus* and 8-9-10-rib cut of the BG's and MM's. Drip loss of the *m. semimembranosus* showed a diet x species x slaughter age interaction, because after 28 days there was no difference ($P>0.05$) between the drip loss of chevon and lamb within a diet, but after 56 days MM's *m. semimembranosus* had a significantly higher drip loss than that of BG's. This agrees with the results of Schönfeld, Naudé, Bok, Van Heerden, Sowden & Boshoff (1993a) who found that sheep meat showed greater drip loss than goat meat. However, it is in contrast with the results of the present investigation where the sensory panel found the chevon to be significantly less juicy than the lamb. The reason for this apparent contradiction, is that juiciness is an organoleptic characteristic related to both the capacity of muscle to release its constitutive water (initial juiciness) and the infiltration fat content (sustained juiciness) (Dryden & Marchello, 1970). In combination with water, the melted lipid constitutes a broth that, when retained in the meat, is released upon chewing. This broth may also stimulate the flow of saliva, and thus improve the meat's apparent juiciness

Table 5. Drip loss, cooking loss and shear force values of the meat of goats and sheep (mean ± SE) receiving either a low or a high energy diet for 28 or 56 days

	BGLE28[1)] (n=8)	BGHE28[2)] (n=8)	MMLE28[3)] (n=8)	MMHE28[4)] (n=8)	BGLE56[1)] (n=8)	BGHE56[2)] (n=8)	MMLE56[3)] (n=8)	MMHE56[4)] (n=8)
Drip loss (%)								
m. semimembranosus	1.54^{bd} ± 0.399	2.53^{ab} ± 0.399	1.39^{d} ± 0.399	1.52^{bd} ± 0.399	3.43^{a} ± 0.399	3.23^{a} ± 0.399	4.84^{c} ± 0.399	4.72^{c} ± 0.399
8-9-10-rib cut	0.95^{abc} ± 0.087	0.78^{acd} ± 0.087	0.61^{d} ± 0.087	0.75^{cd} ± 0.087	1.01^{ab} ± 0.087	1.06^{b} ± 0.087	1.08^{b} ± 0.087	1.11^{b} ± 0.087
Cooking loss (%)								
m. semimembranosus	39.91^{ab} ± 0.636	38.49^{a} ± 0.636	36.29^{d} ± 0.636	33.93^{c} ± 0.636	40.58^{b} ± 0.636	40.97^{b} ± 0.636	39.32^{ab} ± 0.636	39.62^{ab} ± 0.636
8-9-10-rib cut	16.87^{ac} ± 0.767	18.44^{ab} ± 0.767	15.77^{c} ± 0.767	16.90^{ac} ± 0.767	19.64^{b} ± 0.767	18.22^{ab} ± 0.767	15.22^{c} ± 0.767	16.90^{ac} ± 0.767
Shear force (kg/cm^2)								
m. semimembranosus	10.06^{c} ± 0.921	12.13^{ac} ± 0.921	12.02^{ac} ± 0.921	9.80^{c} ± 0.921	13.20^{ab} ± 0.985	15.44^{b} ± 0.921	12.79^{ab} ± 0.985	14.16^{ab} ± 0.921
8-9-1-rib cut	9.47^{b} ± 0.572	7.88^{a} ± 0.572	9.77^{b} ± 0.535	7.29^{a} ± 0.535	11.31^{c} ± 0.535	10.27^{bc} ± 0.572	10.23^{bc} ± 0.535	10.01^{bc} ± 0.572

[1)] BGLE28/56: Low Energy diet, fed to Boer goats for 28/56 days
[2)] BGHE28/56: High Energy diet, fed to Boer goats for 28/56 days
[3)] MMLE28/56: Low Energy diet, fed to Mutton merinos for 28/56 days
[4)] MMHE28/56: High Energy diet, fed to Mutton merinos for 28/56 days
[a,b,c] Means in the same row with different superscripts differ ($P<0.05$)

(Forrest, Aberle, Hendrick, Judge & Merkel, 1975). Thus a certain quantity of free water together with the lubricant effect of fat favour meat palatability (Dryden & Marchello, 1970). In another part of this investigation (Sheridan *et al.*, 2001) a tendency was found for MM's in the 56-day group to have a higher level of marbling fat than BG's on the same diet. Marbling fat that is present serves to enhance juiciness in an indirect way. During cooking, the melted fat becomes translocated along the bands of perimysial connective tissue. This uniform distribution of lipid throughout the muscle may act as a barrier to moisture loss during cooking. Meat with some marbling shrinks less during cooking and remains juicier. Subcutaneous fat also minimises drying and moisture loss during dry heat roasting (Forrest *et al.*, 1975).

In terms of drip loss in the 8-9-10-rib cut, diet did not have an influence within a species. Species also did not significantly influence drip loss within a diet. Present data on both the *m. semimembranosus* and 8-9-10-rib cut, agrees with the findings of Schönfeld *et al.* (1993a) and Webb, Bosman & Casey (1994) who concluded that age had a significant influence on drip loss, since the drip loss of the 56-day group of animals were significantly higher than their contemporaries in the 28-day group.

Cooking loss in the *m. semimembranosus* showed a diet x species x slaughter age interaction. After 28 days the BG's had significantly higher cooking losses than the MM's, but after 56 days no differences ($P>0.05$) were evident. The cooking loss of the MMHE28 seems low, but apart from that, diet had no influence ($P>0.05$) on cooking loss of the *m. semimembranosus*. Cooking loss in the *m. semimembranosus* increased with an increase in slaughter age.

Except for the BGLE56, which had a significantly higher cooking loss than BGLE28, the tendency in the 8-9-10-rib cut was that cooking loss was not influenced by slaughter age or diet within a species or species within a diet. This agrees with the findings of Webb, Bosman & Casey (1994) who concluded that cooking losses in MM's and Dorpers were not affected by dietary energy levels. However, Babiker *et al.* (1990) found that goat meat has significantly superior water holding capacity and less cooking losses than lamb.

In the *m. semimembranosus* diet did not have an influence on the shear force values within a species. The shear force values of the 8-9-10-rib cut had the same trend in the 56 day group as in the *m. semimembranosus*. However in the 28 day group, the meat from the animals on the HE diet was more tender than their contemporaries on the LE-diet (BG: 7.88 vs. 9.47 kg/cm^2; MM: 7.29 vs. 9.77kg/cm^2). Tenderness declined with age in both the BG's and the MM's. This agrees with the findings of Kirton (1970), Gaili *et al.* (1972) and Smith, Pike & Carpenter (1974).

Within a slaughter age group, tenderness was not influenced by species. This is in contrast with the general belief and the results from the sensory panel that goat meat is less tender than lamb. Schönfeld, Naudé, Bok, Van Heerden, Smith & Boshoff (1993b) found that sheep *m. longissimus thoracis et lumborum* and *m. semimembranosus* were significantly more tender than Angora goat

cuts, which in turn were significantly more tender than Boer goat cuts. Similar differences in tenderness were also reported by Kirton (1970), Gaili *et al.* (1972) and Smith *et al.* (1974).
For the organoleptic evaluation, stringiness was defined as the fibres perceived during mastication and the sensory panel found differences in both tenderness and stringiness between BG and MM meat, but the shear force values did not differ between the two species. Therefore it is possible that there is no difference in tenderness between BG meat and lamb when raised under feedlot conditions, but that goats have thicker fibres and therefore the meat is stringier and seems less tender. Differences in fibre thickness between goats and sheep were demonstrated by Gaili *et al.* (1972) and Gaili & Ali (1985). Gaili & Ali (1985) concluded that goats respond more to better nutritional treatment, by increasing fibre thickness, than sheep. The difference between control and fattened animals in mean fibre diameter was greater for goats than sheep. It is possible that the active nature of the goat calls for thicker muscle fibres than those found in sheep.

CONCLUSIONS

It can be concluded from the present investigation that organoleptically there is a difference between chevon and lamb. Each one had a specific species flavour, which is not influenced by the energy level of the diet. BG meat is perceived to be stringier, but its Warner-Bratzler shear force value does not differ from that of MM's. Therefore BG meat probably has thicker fibres than that of MM's, but this theory still needs further investigation. Tenderness declined with age in both species. Juiciness was not influenced by diet within species, but there was a tendency for lamb to be juicier than goat meat, probably due to the fatness code. Chevon had a more pronounced aftertaste than lamb. No objective differences could be distinguished between the colour of the cooked chevon and lamb. After 56 days in the feedlot, MM's *m. semimembranosus* had a significantly higher drip loss than that of BG's. In both the *m. semimembranosus* and 8-9-10-rib cut, drip loss increased with an increase in slaughter age. Cooking loss in the *m. semimembranosus* increased significantly with an increase in slaughter age, but diet energy had no influence ($P>0.05$) on the cooking loss. Diet had no significant effect on the colour parameters of the fresh meat, within a species. There was a tendency for lamb to have a higher a*-value (redness) than chevon. In the 28-day group goat meat was lighter, while sheep meat had a higher b*-value (yellowness) in the 56-day group. Therefore it can be concluded that chevon compares favourably with lamb in terms of water holding capacity, colour and shear force values. When goats are finished in the feedlot, it can be done on a LE-diet, since diet energy level does not influence shear force values, water holding capacity, organoleptic characteristics or colour of the cooked BG meat. This may decrease feed costs.

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GENERAL CONCLUSIONS

One of the reasons why meat supply does not meet human demand is that man has concentrated on relatively few animal species as a source of meat (Gaili & Ali, 1985). Exploitation of unconventional livestock such as goats is advocated as a means of increasing global meat production and consumption (Babiker, El Khider & Shafie, 1990). Goat populations in developing countries represent 94% of the world total. Despite their numerical importance goat meat is little consumed and commands a low price compared with beef and mutton. In 2000 Africa had 22.8% and 29.1% of the total world's sheep and goat populations, respectively (FAO, 2001). Within the African society, sheep and goats comprise a greater proportion of the total wealth of poor families (Peacock, 1996) and are the primary source for meat and meat products. Although South Africa possesses large numbers of domestic ruminants, meat consumption has been limited mainly to sheep and cattle. Goats are used to a lesser extent. This is partly attributed to a general belief that goat meat is inferior to mutton and beef.

Numerous contradictions regarding comparative goat and sheep growth, carcass characteristics and meat composition still exist in literature. Concepts involved with most of the contradictions include average daily gain (ADG), dressing percentage, carcass weight distribution and organoleptic characteristics, especially tenderness, juiciness and flavour, particularly as pertaining to animals reared/grown under intensive/feedlot conditions.

The potential of the Boer goat (BG) as a meat-producing animal has been recognised by early researchers such as Owen & Norman (1977). However, little is known about the performance of goats under intensive conditions. The South African Mutton merino (MM) was selected as a standard to compare with the BG for this investigation. The MM is a dual-purpose breed, developed to produce a slaughter lamb at an early age. It has a high fertility, good conformation, feed conversion efficiency (FCE) and adaptability and is therefore popular in feedlot production systems.

This project was undertaken to obtain more information on the growth, carcass and organoleptic characteristics, as well as meat chemical compositions of BG's in comparison with MM's, under feedlot conditions.

The MM's in this investigation had a significantly higher ADG than the BG's. In terms of FCE the MMHE was more efficient ($P<0.05$) than the MMLE, but the BG's did not show significant differences in FCE between diets. In addition there was no difference in FCE between the MM's and BG's on the same diet.

The BGLE digested DM, CP and energy more efficiently ($P<0.05$) than the MMLE, while there was no apparent difference in the digestibility of any of the components between BGHE and MMHE. BG's on the LE-diet also had a significantly higher energy retention than the MMLE, although this was not evident with animals on the HE-diet. These two findings support the hypothesis that goats perform better on a lower quality feed than sheep, but that sheep and goats have a similar digestive efficiency on a good-quality feed (Aregheore, 1996).

The BGLE digested the DM of their diet more efficiently ($P<0.05$) and had a higher energy retention (% of energy intake) than the BGHE. This may explain why there was no significant difference in ADG and FCE between the BGHE and BGLE. The result of the digestibility trial is that the two diets had the same ME-value for the goats, which confirms that goats perform equally well on a lower quality feed as their contemporaries on a higher one (Morales, Galina, Jimenez & Haenlein, 2000).

The fact that the LE-diet had a significantly higher ME-value for the BG's than for the MM's, indicate that calculated ME-values of diets formulated for sheep can not under all circumstances be used as an indicator of the ME-values for goats.

The Boer goat had a 49 % lower ($P<0.01$) water intake per kg weight gain than the Mutton merino on both the high and low energy diets. Both species had a lower ($P<0.01$) water intake on the high than on the low energy diet. Furthermore, the Boer goat had a daily water intake of only 171 $ml/kg^{0.75}$ compared to the 302 $ml/kg^{0.75}$ of the Mutton merino. The BG has an energy conserving lifestyle, being a bulk and roughage feeder (high fibre, low CP forage), it probably needs less water for metabolism and nitrogen excretion. On the other hand, the MM has been selected and farmed on higher quality pastures (high CP, low fibre forage) and therefore probably needs a higher water turnover for the excretion of nitrogen in the urine as has been demonstrated in the Blesbok and Impala (Fairall & Klein, 1984).

The mass of the liver, empty stomach, head, and feet as a proportion of empty body weight (EBW), was higher in goats than in sheep. The MM's had significantly heavier skins, probably due to wool growth. After 56 days, goats had a significantly higher proportion of edible offal than sheep. Both kidney fat and gastro-intestinal (GIT) fat increased with an increase in the age of both species.

Neither species nor diet influenced the length of the carcasses, although, as expected, the animals slaughtered after 56 days in the feedlot had significantly longer and deeper carcasses than their contemporaries slaughtered after 28 days. Within a species, diet did not influence the breadth of the carcasses. However, species had an influence with the MM having significantly broader and deeper carcasses than the BG's. The goats had less weight per unit carcass length and thus more slender carcasses than the sheep. HE-animals had more weight per unit carcass length than LE-animals, probably due to subcutaneous fat.

MM's had heavier carcasses and proportionally heavier ribs and buttocks than BG's. Since the hindquarter is the most expensive commercial cut, lamb carcasses may give better returns in retail markets than kid carcasses. One implication of these results may be that the goat should be dealt with as an entity in the market place and not be compared to lamb and mutton carcasses. However, since diet did not influence the carcass weight distribution of BG's, goats can be finished on a LE-diet in the feedlot, without compromising the commercial yield of the carcass.

Goat carcasses from young feedlot animals were not inferior to that of lamb in terms of chemical composition. This agrees with the result of Gaili & Ali (1985) and Babiker *et al.* (1990). The BG's 8-9-10-rib cuts (and presumably the carcass) had significantly higher protein levels as well as significantly higher concentrations of 11 of the 18 measured essential amino acids. Gaili & Ali (1985) concluded that the phenomenon that fattened goats have more protein and less intramuscular fat in their muscles than sheep, could be ascribed to a greater rate of protein synthesis during the feeding period in goats than in sheep. Sheep responded to nutritional treatment by depositing more fat and goats responded by laying down more muscle protein. Goat carcasses in our investigation had higher Ca, K, Mg, Na and P-levels than sheep carcasses, regardless of the diet fed. There was a tendency for the goat's *m. semimembranosus* to have a lower Fe-content than that of the sheep.

The BG had significantly lower levels of cholesterol in its 8-9-10-rib cut (and therefore presumably in the carcass) than the MM. Palmitic (C16:0), stearic (C18:0) and oleic (C18:1n9) acid comprised the greatest proportions of the fatty acids in both the *m. semimembranosus* and 8-9-10-rib cuts of both species. This agrees with the results of Casey & Van Niekerk (1985) on BG's and Webb, Bosman & Casey (1997) on MM's. On the HE-diet the MM's *m. semimembranosus* had more ($P<0.01$) saturated fatty acids (SFA), while the BG's had significantly more unsaturated fatty acids (UFA). However, on the LE-diet there was no significant difference between the SFA:UFA ratio of BG's and MM's. BGHE had a significantly higher (and thus more desirable) (C18:0+C18:1):C16:0 ratio in its' *m. semimembranosus*, as well as more desirable fatty acids (DFA; the total of all UFA and C18:0 according to Rhee, 1992) than the MMHE.

The diets fed did not alter the profile of the BG's 8-9-10-rib cut's fatty acids. However, the MMHE had significantly higher proportions of SFA than the MMLE and thus a significantly higher SFA:UFA ratio. On both diets, goats' 8-9-10-rib cuts had a significantly lower SFA:UFA ratios than that of the sheep.

Organoleptically there was a difference between the goat and sheep *m. gracilis*. Each has a specific species flavour, which is not influenced by the energy level of the diet. In contrast to the present data, Gaili, Ghanem & Mukhtar (1972) found no species differences in flavour of lamb and goat meat. BG meat was perceived to be stringier, but its Warner-Bratzler shear force value did not differ from that of MM's. Therefore BG meat probably has thicker fibres than that of MM's, but this theory still needs further investigation. Tenderness declined with age in both species. Juiciness was not influenced by diet within species, but there was a tendency for lamb to be juicier than goat meat, probably due to the fatness code. BG meat had a more pronounced aftertaste than lamb. No objective differences could be distinguished between the colour of the cooked chevon and lamb. After 56 days in the feedlot, MM's *m. semimembranosus* had a significantly higher drip loss than that of BG's. In both the *m. semimembranosus* and 8-9-10-rib cut, drip loss increased with an increase in slaughter age. This agrees with the results of Schönfeld, Naudé, Bok, Van Heerden, Sowden & Boshoff (1993) and Webb, Bosman & Casey (1994). Cooking loss in the *m. semimembranosus* increased significantly with an increase in slaughter age, but diet energy had no influence ($P>0.05$) on the cooking loss. Diet had no significant effect on the colour parameters of the fresh meat, within a species. There was a tendency for lamb to have a higher a*-value (redness) than chevon. In the 28-day group, goat meat was lighter, while sheep meat had a higher b*-value (yellowness) in the 56-day group.

The results of this investigation may render the BG economically viable for feedlot finishing. Due to its low price in the abattoir, goat meat can replace lamb and mutton, particularly among low-income groups. Since diet energy level did not influence the growth, carcass weight distribution, water holding capacity, colour, shear force values or organoleptic qualities of chevon, BG's may be finished on a diet with a lower ME-value than which is usually formulated for sheep, without a reduction in performance. This may render a direct economic advantage for BG feedlot finishing. Meat from young feedlot goats is not inferior to that of lamb and it has a higher protein and lower fat percentage. On a high energy feedlot diet, goats have a significantly lower carcass cholesterol content and SFA:UFA ratio than sheep. Therefore chevon can be considered as a healthy food commodity, especially among people wishing to consume a low cholesterol, SFA and calorie diet.

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