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A comparison of selected nutritional parameters between wild and domestic meats

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1. Introduction

1.1 Dietary Lipid

Fat, an essential element in our diet, is not only an effective energy source, but also is the source of the two essential fatty acids (EFA) – linoleic and α-linolenic acids. EFA's are fatty acids that mammals require but are not able to produce and therefore need to be obtained through the diet (Sanders, Johnson, O'Dea, and Sinclair, 1994). These EFAs and the longer chain more unsaturated derivatives mammals produce from them play a structural role in the phosphoglycerides of cell membranes, as well as being the precursors of eicosanoids (prostaglandins, prostacyclins, thromboxanes and leukotrienes) (Moscatelli, 1972). Dietary fat is also required to facilitate the absorption of the fat-soluble vitamins, vitamin A, D, E and K. These vitamins bind to ingested lipids and are absorbed with their digestion products (Sanders *et al*, 1994).

It has been shown that dietary fat has a significant effect on blood cholesterol levels and therefore potentially on the risk of cardiovascular disease (CVD) (McNamara, 1993). Within the total dietary lipid, it has also been demonstrated that various lipid components have significant and varied influences on the plasma cholesterol concentration. Although the current study does not report on direct impacts on human health, the results may nevertheless be of great significance for future recommendations in regard to nutrition-related diseases.

Over the past several decades the main focus of dietary recommendations has been a decrease in total fat intake. Low-fat, high carbohydrate diets have been recommended as a way to decrease the risk of CVD. Since 1980, when the American Dietary Guidelines were

first issued (USDA/USDHHS, 1980), a few important but subtle changes have occurred, in order to try to convey a positive message (Dixon, and Ernst, 2001; Hu, Manson, and Willett, 2001). In light of this, in the year 2000 the role of total fat as a major risk factor of CVD was de-emphasized (Table 1). Paralleling this, so have the South African Food Based Dietary Guidelines been modified over the years. They now read “Use Fat Sparingly”, and try to convey a positive, easy to follow message, although the word “sparingly” may create confusion, as it is too vague; perhaps approximate quantities are still needed (Love, Maunder, Green, Ross, Smale-Lovely, and Charlton, 2001).

TABLE 1: Modifications in American Dietary Guidelines from 1980 to 2000

1980	**Avoid** too much fat, saturated fat and cholesterol.
1990	**Choose** a diet **low** in fat, saturated fat and cholesterol
2000	Choose a diet low in saturated fat, cholesterol and **moderate** in **total** fat

(Taken from Dixon and Ernst, 2001)

The quantitative impact of fat on plasma cholesterol levels, and therefore on the potential risk of CVD can be estimated using equations developed by Keys and Hegsted (Hegsted *et al,* 1956) (Table 2) (McNamara, 1993). More recently, Mensink has confirmed that this equation is able to predict serum cholesterol changes (Mensink, 1992) (Table 2). By use of these equations it is possible to estimate the effects of proposed dietary changes on plasma cholesterol levels, and ultimately on the risk of CVD and mortality (McNamara, 1993).

TABLE 2: Equations used to estimate cholesterol change resulting from dietary fat and cholesterol modifications.

Keys Equation: ΔCholesterol = 1.35(2ΔS-ΔP) + 1.52ΔZ
Hegsted Equation: ΔCholesterol = 2.16ΔS – 1.65ΔP + 0.097ΔC
In which ΔS is the change in percentage of calories from saturated fat, ΔP is the change in percentage of calories from polyunsaturated fat, ΔZ is the difference between the square root of the initial and subsequent intake of cholesterol (mg/1000kcal), and ΔC is the difference in cholesterol intake (mg/1000kcal)
Mensink Equation: ΔTC=1.2(1.8ΔS - 0.1ΔM - 0.5ΔP), in which ΔTC is the change in serum cholesterol values (mg/dl), ΔS is the change in percentage energy from lauric, myristic and palmitic acids, ΔM is the change in percentage energy from monounsaturated fatty acids, and ΔP is the change in percentage energy from polyunsaturated fatty acids

(Adapted from McNamara, 1993)

1.2 Dietary history

For a large part of history Man has followed a hunter-gatherer type diet, and communities still following such lifestyles do not generally show high rates of CVD. It is only since the transition to a more westernised diet that an increase in CVD has been noted. By comparing both diets we can see that a significant proportion of both are meat, with the hunter-gatherer diet associated with wild game and the westernised diet with domesticated meat. As a result, many authors have recommended the removal of meat, particularly meat fat, from the diet as a means of reducing CVD risk (Albert, Campos, Stampfer, Ridker, Manson, Willett, and Ma, 2002; Crawford, 1968; Gutierrez Fuentes, 1996; Hu, Bronner, Willett, Stampfer, Rexrode,

Albert, Hunter, and Manson, 2002; Hu FB *et al*, 2001. Hu, Stampfer, Manson, Rimm, Colditz, Rosner, Hennekens, and Willett, 1997).

Scientific evidence is accumulating that lean meat itself is not a risk factor for CVD, but the risk rather stems from the excessive fat and particularly saturated fat associated with the meat of domesticated animals raised using modern agricultural practices (Cordain, Watkins, Florant, Kelher, Rogers, and Li, 2002; Crawford, Gale, Woodford, and Casped, 1970). This high saturated fat content from domestic meat is due, not only to the nature of the meat, but to the occurrence of marbling, that is the deposition of triacylglycerol droplets in lean muscle tissue. Domestic meat has also been found to have low polyunsaturated fatty acid (PUFA) levels, which also adversely impacts on the risk of CVD (Crawford,1968; Crawford *et al*, 1970; Sinclair, and O'Dea,1991). In parallel, Enser, Hallett, Hewitt, Fursey and Wood (1996) described "Diseases of the Western Civilization". In their research they showed that although the recommended ratio of n6 to n3 fatty acids should be 2:1, in the current British diet that figure has escalated to approximately 10:1, and that meat was a major contributor. Thus one recommendation was to reduce, if not eliminate, meat consumption.

However, the population at large is unlikely ever to completely stop eating meat, as habits are very difficult to change, and the simplest and cheapest possibility is to try changing the meat content of people's diets from domesticated meat, predominantly high in saturated fat, to wild game with its associated increased levels of PUFAs. In doing so, people would revert closer to a hunter-gatherer type diet, low in saturated fat and cholesterol and high in PUFA and EFA. This shift in diet would likely benefit the population by decreasing the risk of CVD and mortality associated with a high saturated fat and low PUFA intake.

One way to facilitate this process would be to substitute meat from domestic sources with that from wild species. It has already been established that tourists to South Africa enjoy eating our game meat (Hoffman, Crafford, Muller, and Schutte, 2003) and although currently game meat is largely only available at specialist restaurants and retailers, if demand increased significantly, production would be stimulated. It might also be possible to supplement domesticated animals with specific lipids but this would probably be an expensive option.

1.3 Dietary Lipid Categories

Dietary fat can be divided into 5 main categories. Each of these fat types has a particular influence on plasma cholesterol levels and ultimately on CVD risk.

1.3.1 Total Fat

Browner, Westenhouse, and Tice (1991) estimate that restricting dietary fat to 30% of the energy intake could decrease CVD mortality by between 5 and 20%. It has also been shown that a decrease in total fat is not as effective as a decrease in saturated fat, because total fat is not strongly associated with CVD (Browner *et al*, 1991). However, an increase in total fat is indirectly linked to the risk of CVD, particularly in obese patients, as it is known that obesity predisposes to CVD (O'Dea and Sinclair, 1982).

An increase in total fat results in an increase in both high-density lipoprotein (HDL) and low-density lipoprotein (LDL) (Sanders *et al* 1994). HDL transports excess cholesterol from the peripheral tissue to the liver where it is broken down and forms part of bile, HDL therefore promotes the removal of cholesterol from the periphery. LDL, in contrast, transports endogenously synthesised cholesterol from the liver making it available to peripheral cells

(Sanders *et al* 1994). Thus an increase in both HDL and LDL is not effective as they counteract each other.

1.3.2 Saturated Fat

A consistent finding in both clinical and epidemiological studies is that the percentage of saturated fat calories in the diet is positively correlated with plasma cholesterol levels and therefore with the risk of CVD (Hegsted, and Ausman, 1988; Hu *et al* 2001; O'Dea, and Sinclair, 1982).

An increase in saturated fat tends to increase cholesterol production in the liver, by providing increased levels of the cholesterol precursor, acetyl-CoA, via β-oxidation. This in turn induces increased LDL concentrations to transport that cholesterol to peripheral cells via the plasma (O'Dea, and Sinclair, 1982). At the same time, saturated fat is known to decrease the activity of Δ-6-desaturase, the enzyme that converts linoleic acid and α-linolenic acid to γ-linolenic acid (GLA) and octadecatetraenoic acid (18:4n3) respectively. Linoleic acid and γ-linolenic acid are both PUFAs that have been shown to decrease plasma cholesterol, but GLA is more potent than linoleic acid. By decreasing the activity of Δ-6-desaturase there is thus a decrease in the suppression of plasma cholesterol and hence a potential increase in the risk of CVD (Horrobin, and Manku, 1983).

It has, however, been shown that not all saturated fatty acids increase cholesterol levels. Only three (lauric acid – C12:0, myristic acid – C14:0 and palmitic acid – C16:0) do so, and these three together form approximately 26% of dietary fat. This finding suggests that stearic acid (C18:0), the predominant fat in hydrogenated vegetable oils derived from oils rich in oleic and

linoleic acids, does not increase cholesterol levels and the recommendation to decrease this may therefore be unjustified (Hu *et al* 2001).

1.3.3 Monounsaturated fat

It has been shown that when dietary saturated fat is replaced with monounsaturated fat there is a marked decrease in plasma cholesterol levels (Hu *et al*, 1997). This decrease in cholesterol is, in turn, associated with a decreased risk of CVD. Hu *et al* (1997) also showed that replacing saturated and trans-unsaturated fats with monounsaturates is more effective in preventing CVD than decreasing total fat intake.

1.3.4 Trans-Unsaturated Fats

Trans-unsaturated fats seem to work by similar mechanisms to saturated fats, since they are both metabolised by the same pathways (Hu *et al*, 1997). Trans-unsaturated fats cause an increase in LDL, and they have also been shown to decrease the activity of the enzyme Δ-6-desaturase, very much in parallel to the effects of saturated fat (Horrobin, and Manku, 1983). Thus an increase in trans-unsaturated fats leads to an increased risk of CVD.

1.3.5 Polyunsaturated Fat

There are 3 families of PUFAs: n9, n6 and n3 PUFA. Each of these families has a parent fatty acid - oleic acid, linoleic acid and α-linolenic acid, respectively. These parent fatty acids are converted into long chain PUFA through the sequential actions of Δ-6, Δ-5 and Δ-4-desaturase (Sanders *et al*, 1994).

1.3.5.1 N9 PUFA

n9 PUFA decrease cholesterol levels by increasing the clearance of LDL cholesterol, there is therefore less cholesterol available to be transported to the cells (Horrobin, and Manku, 1983). However, significant production of n9 PUFAs only occurs when linoleic and α-linolenic acids (EFAs) are lacking in the body. Under these circumstances oleic acid is converted to its longer, more unsaturated derivative, eicosatrienoic acid (C20:3n9). The presence of this acid in tissue lipids is a unique and sensitive biochemical marker of EFA deficiency (Sinclair, and O'Dea, 1991). Thus, even though n9 PUFA decrease cholesterol, as they do not occur at any significant levels in normal tissues, they are unlikely to be significant contributors to cholesterol clearance in normal humans.

1.3.5.2 N6 PUFA

n6 PUFA tend to decrease plasma cholesterol levels, but are not as effective as n9 PUFA. Linoleic acid, specifically, has been known for more than 30 years to decrease elevated cholesterol levels, therefore a large increase in linoleic acid has been recommended to decrease the risk of CVD, although the precise mechanism whereby linoleic acid decreases cholesterol levels is still unclear (Horrobin, and Manku, 1983). Linoleic acid is converted to its first metabolite, γ-linolenic acid by the enzyme Δ-6-desaturase, and γ-linolenic acid has been shown to be 170 times more potent in lowering plasma cholesterol levels than its parent (linoleic acid), therefore the cholesterol-lowering mechanism is most likely to involve γ-linolenic acid (Horrobin, and Manku, 1983) (see 1.3.2 above).

The n6 PUFA, arachidonic acid (AA), the precursor of 2-series eicosanoids (prostaglandins, prostacyclins, leukotrienes, and thromboxanes) is derived either from linoleic acid or directly

from the diet (Li, Ng, Mann, and Sinclair, 1998; Sanders *et al*, 1994; Sinclair, and O'Dea, 1991). AA and its eicosanoid metabolites play important roles in inflammation, the regulation of immunity, platelet aggregation and thrombosis (Li *et al*, 1998; Mann, Johnson, Warrick, and Sinclair, 1995; Moscatelli, 1972). It is therefore important that adequate amounts of AA are obtained, either via de novo synthesis from linoleic acid or from the diet. However, Western diets generally provide excessive amounts of AA and thus may induce overproduction of 2-series eicosanoids.

1.3.5.3 N3 PUFA

Fish oils are particularly rich in n3 PUFA and these are known to decrease the risk of CVD in communities eating a lot of marine products, e.g. Inuit (Eskimos). They traditionally eat a diet high in fat, and yet show a decreased incidence of CVD. This is because their diet is comprised mainly of fish and seal meat, which are high in n3 PUFA, particularly eicosapentaenoic and docosahexaenoic acids (EPA and DHA, respectively) (Moscatelli, 1972; Sinclair, and O'Dea, 1991). In fact, studies have found an inverse correlation between fish consumption and CVD mortality, although fish is more effective in decreasing the risk of fatal CVD than it is in decreasing the risk of non-fatal CVD (Horrobin, and Manku, 1983; Hu, *et al*, 2001). The protective nature of n3 fatty acids is possibly due to several mechanisms, including a decrease in platelet aggregation, and a reduction in plasma triacylglycerol levels, as well as anti-arrhythmic effects (Horrobin, and Manku, 1983; Hu, *et al*, 2001). Although there is accumulating data that n3 fatty acids are strongly associated with a decreased risk of CVD and sudden death amongst men (Albert, *et al*, 2002), limited data was available on CVD in women until a recent study by Hu *et al* (2002). This study demonstrated that increased consumption of fish and n3 fatty acids is also associated with a decreased risk of CVD amongst women (Hu *et al*, 2002).

1.4 Lipids of Meat

Epidemiological studies have shown that in populations with diets low in fat and cholesterol, CVD and thrombosis are less prevalent than in populations with high fat and cholesterol consumptions (Gutierrez Fuentes, 1996). It has been shown that an effective way to decrease the risk of CVD is to decrease total fat intake from 40% to 30% of total calories, and with only 10% of those coming from saturated fat, as well as decreasing cholesterol intake from around 500mg/day to less than 300mg/day (Gutierrez Fuentes, 1996).

It has been proposed that in order to achieve a decreased cholesterol intake, a decrease in red meat intake should be advocated and therefore, an increase in the use of chicken, turkey and fish as substitutes. By doing so we would decrease our total fat and saturated fat intake and yet would also increase our PUFA intake (Eagle, Hober, DeSanctis, and Austen, 1989; Gutierrez Fuentes, 1996). However, as indicated above (1.2), the majority of the population are likely to be very resistant to such a large change in dietary lifestyle. Such a change would also require a huge re-orientation of a major sector of the agricultural industry, a change which is also extremely unlikely.

A pilot study carried out in this laboratory during 2002, analysed the fatty acid profiles of some South African wild game meats (crocodile, eland, gemsbok, giraffe, hartebeest, kudu, ostrich, sable and zebra) in comparison to some domestic meats (beef, chicken, lamb and pork). In this study, across the wild game species a decrease in total saturated fat, monounsaturated fat and AA and an increase in total polyunsaturated fat were noted, when compared to the domestic species. Similarly, No differences in DHA were found. It is therefore possible that wild game meat may decrease the risk of CVD, as it is clearly established that a decrease in saturated fat and an increase in polyunsaturated fat tends to decrease the risk of this disease.

The decrease in AA seen as well may also be beneficial because of the effects it is known to produce via its eicosanoid metabolites (see 1.3.7 above).

However, this was a pilot study and not exhaustive. Thus certain factors may have contributed to variations within the fatty acid profiles obtained:

1. Variability between samples could be attributed to the domestic meats being sampled only once and from a single source. Wild samples, although obtained more than once, were also obtained from a single source.
2. Fatty acid profiles may differ between different cuts of meat, for example the hind quarter of an animal may have increased saturated fat content when compared to the fore quarter of that animal.
3. Age may influence fatty acid profiles, as young animals may potentially differ significantly from older animals.
4. The diet of the animals may potentially be the most important contributing factor, as this may lead to an accumulation of interfascicular adipocytes, i.e. marbling. Marbling increases the saturated fat content of the meat, and this increase in saturated fat may potentially increase the risk of CVD.
5. Geographical location of animals as well as seasonal variations may also affect the fatty acid profiles obtained.

This current study significantly develops beyond the pilot study. In this study lipid variation between various muscle types and sites was investigated as well as within and across certain species. Total protein and energy content of both the wild game and domestic meats were also analysed, to assess whether these parameters vary in parallel under South African conditions. This permitted an assessment of whether several parameters varied between wild

and domestic animals or merely the lipid profile. Protein and energy were assessed to determine whether it was merely the fatty acid profiles which varied between species or whether other measurable parameters also varied. Various muscle types were assessed because, as different types of skeletal muscle perform different functions and therefore may require different fatty acid profiles.

The species included in this study, were species where it was possible to obtain specific cuts of meat directly from the carcass immediately post mortem, and usually under the supervision of the author. This did however exclude chicken, cattle and sheep, from which such samples could not repeatedly and reliably be obtained during the time period of the study.

2. Materials and Methods:

2.1 Samples

Samples were obtained from two sources: samples of 'wild' meats from a Provincial reserve in Lichtenburg and 'domestic' samples from the University of Witwatersrand Central Animal Services. Wild species were selected on the basis of availability during the period of this study; domestic species were those available through the University of Witwatersrand Central Animal Services. The domestic species sampled comprised pig, goat and rabbit, while the wild species sampled consisted of blue wildebeest, impala and springbok.

The pig *(Sus domestica)*, goat *(Capra hircus)*, blue wildebeest (*Connochaetes taurinus)*, impala *(Aepyceros melampus)* and springbok *(Antidorcus marsupialis)* belong to the order of Artiodactyls, which are characterised by their hoofed, even digited (two or 4 toed) feet (Solomon, *et al*, 1996). The rabbit *(Oryctolagus cuniculus)* belongs to the order of Lagomorpha, which includes hares and pikas. Lagomorpha like rodents, have chisel-like incisors, as well as long hind legs adapted for jumping, and long ears (Solomon, *et al*, 1996).

The samples were frozen at –20°C until required for analysis. All meat samples were trimmed of excess adipose tissue before being analysed. Samples from seven sites in each animal were analysed: rump, neck, midback, thigh and flank. An overall profile for meat from each animal was estimated by averaging the results from rump, neck, midback, thigh and flank.

2.2 Lipid Analysis:

Samples of intact tissue were weighed and lipids were extracted with chloroform : methanol in the ratio of 2 to 1 and the extracts were stored at -20°C (Folch, Lees, and Sloane-Stanley,

1957). Lipid dry weights were determined using 1ml aliquots of the above mentioned extracts. These aliquots were dried to allow for gravimetric determination of lipid content. Using boron trifluoride in methanol, fatty acid methyl esters (FAME) were prepared from 20mg of each lipid sample (McNamara, 1993). FAME analyses were performed using a Varian 3400 gas chromatograph with 4270 integrator and a 10% SP2330 column run isothermally at 195°C. Fatty acids were then identified by comparison to the retention times of known fatty acid standards.

2.3 Protein and Energy Analysis:

Samples of intact tissue for both protein and energy analyses were desiccated and stored. Aliquots of the desiccated samples were used to perform the analyses according to methods standard in the School of Physiology (See 2.3.1 and 2.3.2 below).

2.3.1 Protein Analysis:

Total protein concentrations were determined by the Lowry Method (Lowry, Rosebrough, Farr, and Randall, 1951), modified to a micro method performed in 96-well micro plates, and using bovine serum albumin as the standard protein (Sigma, St Louis, USA)

2.3.2 Energy Analysis:

In order to assess total energy concentration, bomb calorimetry (Haderslev, Jeppesen, Sorensen, Mortensen, and Staun, 2003) was performed using an Automatic Caloric Processor CP500 bomb calorimeter.

2.4 Data Analysis:

2.4.1 Lipid

Statistical analysis used Instat® (GraphPad Inc, San Diego CA, USA). Means and standard deviations were calculated and tabulated. Statistical significance of results was tested as follows;

1. For paired data i.e. within the same animal for variables rump, neck, midback, thigh and flank the Student's paired t-test was used. Significance of differences were assessed using 'p' and were considered significant when $p < 0.05$.
2. For between species and between source comparisons Student's t-test for independent samples was used. Significance of differences were assessed using 'p' and were considered significant when $p < 0.05$.

2.4.2 Protein and Energy

Protein and energy content were analysed, but, as lipid analysis was the main focus of this research, not all samples per species were large enough to allow for sufficient protein and energy analysis as well as lipids. Indeed, for the springbok flank no samples were available. It was therefore impossible to perform valid statistical analysis, but from looking at the data there were no apparent differences between wild and domestic meat samples with regard to both protein and energy.

As there was at least one value for each site (excluding springbok flank), total, overall energy and protein differences could, therefore, be established. These total values were determined

using averages of the mean and standard deviations of the individual muscles i.e. rump, neck, midback, thigh and flank.

2.5 Ethics

Whilst no animals were killed specifically for this study and all samples were obtained serendipitously, clearance was obtained from The University of Witwatersrand Animal Ethics Screening Committee.

- Clearance certificate number (wild meats): 2001 84 1
- Clearance certificate number (domestic meats): 2003 35 1

3. Results and Discussion

All data are shown in the Tables below. However, for the sake of brevity and clarity, only data shown to be statistically significantly different (i.e. $p<0.05$) are described.

3.1 Individual Domestic Species

3.1.1 Pig

Three pigs were sampled in the University of Witwatersrand Central Animal Services. Samples were taken from five sites throughout the body, i.e. rump, neck, midback, thigh and flank. These samples were used for lipid, protein and energy analysis.

3.1.1.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 3 below.

Lipid dry weight was significantly higher in pig neck compared to pig midback ($p=0.048$). When comparing pig neck to pig thigh total saturated fat (TS) was significantly higher ($p=0.018$) in pig neck, and α-docosapentaenoic acid (22:5n3) was significantly lower ($p=0.017$) in pig neck. Total polyunsaturated fatty acids (TP) were significantly higher in pig neck when compared to pig flank ($p=0.041$). When comparing pig thigh to pig flank, TS was significantly lower ($p=0.011$) in pig thigh, total n6 fatty acids (Tn6) and total polyunsaturated fatty acids (TP) were significantly higher in pig thigh ($p=0.017$ and $p=0.013$ respectively), lipid dry weight was significantly lower in pig thigh ($p=0.038$).

We have shown that a higher lipid dry weight is associated with pig neck when compared to pig midback. When comparing pig neck to pig thigh, there was a higher concentration of total

saturated fat (TS) in pig neck, and a lower concentration of α-docosapentaenoic acid (22:5n3) in pig neck. Pig neck was found to have a higher concentration of total polyunsaturated fatty (TP) acids when compared to pig flank. When comparing pig thigh to pig flank, there was a lower concentration of TS and lipid dry weight, and a higher concentration of total n6 fatty acids (Tn6) and total polyunsaturated fatty acids (TP) in pig thigh.

TABLE 3: Fatty acid profile of various muscle sites of pig

	RUMP		NECK		MIDBACK		THIGH		FLANK		TOTAL	
	X	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**
TS	**29.58**	**7.31**	**34.64**	**8.68**	**31.63**	**8.67**	**31.43**	**7.60**	**37.67**	**9.01**	**32.99**	**3.18**
TM	**36.32**	**16.34**	**37.28**	**17.57**	**36.90**	**11.83**	**32.81**	**14.67**	**38.70**	**22.33**	**36.40**	**2.19**
18:2	16.26	3.05	15.22	5.49	18.30	4.06	14.34	4.82	13.99	4.93	**15.62**	**1.74**
20:4	3.33	2.40	3.63	1.82	5.03	0.01	6.91	4.87	2.75	1.90	**4.33**	**1.67**
22:4	-		0.52	0.01	0.50	0.01	0.50	0.01	0.63	0.01	**0.54**	**0.06**
22:5	1.16	0.39	0.99	0.27	0.96	0.07	1.19	0.17	0.92	0.01	**1.04**	**0.12**
Tn6	**24.34**	**6.45**	**20.98**	**6.30**	**25.42**	**7.62**	**23.58**	**6.01**	**18.80**	**5.79**	**22.62**	**2.69**
18:3	1.39	0.05	0.85	0.39	0.90	0.38	1.25	0.35	1.25	0.46	**1.13**	**0.24**
20:5	15.85	0.01	0.63	0.01	1.11	0.01	-		-		**5.86**	**8.65**
22:5	1.26	0.07	1.11	0.05	1.25	0.06	1.59	0.04	1.17	0.01	**1.28**	**0.18**
22:6	4.23	0.38	4.72	1.38	4.83	0.01	4.38	0.64	2.28	0.78	**4.09**	**1.04**
Tn3	**23.40**	**6.39**	**7.97**	**1.76**	**8.80**	**1.73**	**8.08**	**1.60**	**5.44**	**0.65**	**10.74**	**7.19**
TP	**47.74**	**0.66**	**28.95**	**9.20**	**34.22**	**11.75**	**31.66**	**10.96**	**24.24**	**9.44**	**33.36**	**8.84**
Dry	**8.67**	**2.08**	**14.67**	**3.79**	**5.00**	**-**	**8.67**	**3.21**	**15.33**	**5.51**	**10.47**	**3.66**
S:P	**0.62**		**1.20**		**0.92**		**0.99**		**1.55**		**1.06**	
n6:n3	**1.04**		**2.63**		**2.89**		**2.92**		**3.45**		**2.59**	

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.
- = not detected

If one is choosing a cut of pig for consumption it is preferable not to choose pig flank or pig neck as these are associated with increased saturated fat contents and therefore an increase in the risk of CVD. Pig neck, although high in saturated fat was also high in polyunsaturated fat. The effects of saturated fat (increasing CVD) and polyunsaturated fat (decreasing CVD) may cancel each other out. Pig thigh may be the best option as it is high in both total polyunsaturated fats and n6 fatty acids thereby decreasing the risk of CVD.

3.1.1.2 Protein

The results from quantifying protein concentrations are shown in Table 4 below. There were no significant differences.

TABLE 4: Protein concentrations of various muscle sites of pig

Pig	Protein concentration (g/g)
Rump	1.72
Neck	1.78
Midback	1.71
Thigh	1.61
Flank	1.98
Total: MEAN (SD)	**1.76(0.14)**

3.1.1.3 Energy

The results from quantifying energy content are shown in Table 5 below. There were no significant differences.

TABLE 5: Energy content of various muscle sites of pig

Pig	Energy content kJ/g
Rump	23.26
Neck	21.74
Midback	21.50
Thigh	22.44
Flank	22.53
Total: MEAN (SD)	**22.29(0.07)**

3.1.2 Rabbit

Three rabbits were obtained from the University of the Witwatersrand Central Animal Service. Samples were taken from five sites throughout the body, i.e. rump, neck, midback, thigh and flank. These samples were used for lipid, protein and energy analysis.

3.1.2.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 6 below.

When comparing rabbit rump to rabbit neck, docosahexaenoic acid (22:6n3) was significantly higher in rabbit rump ($p=0.047$). Linoleic acid (18:2n6) was significantly higher in rabbit neck compared to rabbit midback ($p=0.043$). Linoleic acid (18:2n6) and n6 fatty acid to n3 fatty acid ratio (n6:n3) was significantly higher in rabbit neck compared to rabbit thigh ($p=0.045$ and $p=0.043$ respectively). When comparing rabbit neck to rabbit flank, saturated fatty acid to polyunsaturated fatty acid ratio (S:P) as well as n6 fatty acid to n3 fatty acid ratio (n6:n3) was significantly higher in rabbit neck ($p=0.029$ and $p=0.044$ respectively).

When comparing rabbit rump to rabbit neck, there was a higher concentration of docosahexaenoic acid (22:6n3) associated with rabbit rump. Linoleic acid (18:2n6) was higher in rabbit neck compared to rabbit midback. There was a higher concentration of linoleic acid (18:2n6) and n6 fatty acid to n3 fatty acid ratio (n6:n3) in rabbit neck compared to rabbit thigh. When comparing rabbit neck to rabbit flank, saturated fatty acid to polyunsaturated fatty acid ratio (S:P) as well as n6 fatty acid to n3 fatty acid ratio (n6:n3) was higher in rabbit neck .

TABLE 6: Fatty acid profile of various muscle sites of rabbit

	RUMP		NECK		MIDBACK		THIGH		FLANK		TOTAL	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
TS	**32.38**	**8.78**	**33.70**	**9.75**	**25.90**	**6.54**	**27.18**	**8.20**	**21.33**	**5.87**	**28.10**	**5.03**
TM	**33.68**	**11.22**	**33.77**	**12.86**	**38.53**	**9.03**	**37.62**	**8.90**	**37.78**	**11.83**	**36.28**	**2.35**
18:2	18.60	2.16	23.69	1.02	13.99	3.00	17.09	6.99	19.09	4.89	**18.49**	**3.52**
20:4	4.22	2.51	1.73	0.54	4.31	0.01	3.66	0.01	2.81	2.56	**3.35**	**1.08**
22:4	0.90	0.16	-		0.77	0.01	0.68	0.09	0.53	0.01	**0.72**	**0.15**
22:5	1.00	0.01	-		0.95	0.01	1.21	0.01			**1.05**	**0.13**
Tn6	**24.72**	**8.42**	**25.42**	**8.42**	**20.78**	**5.70**	**23.20**	**7.07**	**22.43**	**11.83**	**23.31**	**1.84**
18:3	1.06	0.22	1.60	0.77	1.04	0.01	1.14	0.54	1.52	0.42	**1.27**	**0.27**
20:5	1.57	0.01	-		5.06	0.01	2.65	0.01	5.85	4.88	**3.78**	**2.00**
22:5	0.61	0.01	-		0.63	0.01	-		-		**0.62**	**0.01**
22:6	7.24	3.43	3.74	3.85	11.79	6.65	13.59	10.56	9.91	11.32	**9.25**	**3.88**
Tn3	**11.14**	**2.83**	**5.34**	**2.83**	**19.79**	**4.73**	**18.46**	**6.03**	**17.28**	**4.19**	**14.40**	**6.05**
TP	**35.86**	**9.60**	**30.76**	**9.60**	**40.57**	**0.70**	**41.65**	**3.35**	**39.71**	**3.65**	**37.71**	**4.46**
Dry	**12.33**	**8.02**	**20.33**	**10.69**	**11.33**	**6.11**	**9.67**	**5.51**	**20.00**	**11.14**	**14.73**	**8.30**
S:P	**0.90**		**1.10**		**0.64**		**0.65**		**0.54**		**0.77**	
n6:n3	**0.69**		**0.83**		**0.51**		**0.56**		**0.56**		**0.63**	

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.
- = not detected

3.1.2.2 Protein

The results for quantifying protein concentration are shown in Table 7 below. There were no significant differences.

TABLE 7: Protein concentrations of various muscle sites of rabbit

Rabbit	Protein concentration g/g
Rump	1.41
Neck	1.28
Midback	1.66
Thigh	1.88
Flank	1.58
Total: MEAN (SD)	**1.56(0.23)**

3.1.2.3 Energy

The results for quantifying energy concentration are shown in Table 8 below. There were no significant differences.

TABLE 8: Energy content of various muscle sites of rabbit

Rabbit	Energy content kJ/g
Rump	22.50
Neck	26.73
Midback	22.53
Thigh	22.15
Flank	26.31
Total: MEAN (SD)	**24.04(2.27)**

3.1.3 Goat

Four goats were obtained from the University of Witwatersrand Central Animals Services. Samples were taken from five sites throughout the body, i.e. rump, neck, midback, thigh and flank. These samples were used for lipid, protein and energy analysis.

3.1.3.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 9 below.

Linoleic acid (18:2n6) and total n6 fatty acids (Tn6) was significantly higher in goat rump compared to goat midback ($p=0.042$ and $p=0.028$ respectively). Arachidonic acid (20:4n6) was significantly lower in goat midback compared with goat thigh ($p=0.037$). Lipid dry weight was significantly higher in goat midback compared to goat flank ($p=0.022$) and

docosahexaenoic acid (22:6n3) was significantly lower in goat thigh compared to goat flank (p=0.023).

We have shown that there are higher concentrations of linoleic acid (18:2n6) and total n6 fatty acids (Tn6) in goat rump compared to goat midback. Arachidonic acid (20:4n6) was lower in goat midback compared with goat thigh. When comparing between goat midback and goat flank, the lipid dry weight was higher in goat midback. Docosahexaenoic acid (22:6n3) was found to have a lower concentration in goat thigh to with goat flank. Goat rump is a preferred choice to goat midback as it contains higher concentrations of n6 fatty acids which are known to decrease the risks of CVD.

TABLE 9: Fatty acid profile of various muscle sites of goat

	RUMP		**NECK**		**MIDBACK**		**THIGH**		**FLANK**		**TOTAL**	
	X	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**	**X**	**SD**
TS	**32.84**	**8.88**	**33.68**	**7.88**	**31.15**	**7.05**	**34.59**	**7.66**	**36.03**	**7.20**	**33.66**	**1.83**
TM	**46.06**	**21.02**	**52.18**	**17.94**	**45.16**	**22.05**	**46.53**	**17.11**	**48.57**	**16.65**	**47.70**	**2.80**
18:2	6.44	9.69	6.38	2.30	3.42	3.03	8.05	1.79	4.83	2.74	**5.82**	**1.76**
20:4	3.39	0.73	3.32	1.88	2.71	1.27	4.31	0.90	4.92	1.55	**3.73**	**0.88**
22:4	0.69	0.01	-		-		-		-		**0.69**	**0.01**
22:5	0.69	0.36	0.72	0.23	0.97	0.01	1.02	0.44	1.27	0.48	**0.93**	**0.24**
Tn6	**11.90**	**2.55**	**11.15**	**2.69**	**7.97**	**1.27**	**14.26**	**3.39**	**13.91**	**1.74**	**11.84**	**2.53**
18:3	0.72	0.01	0.80	0.51	0.68	0.36	0.75	0.19	1.09	0.26	**0.81**	**0.16**
20:5	0.73	0.27	-		-		-		-		**0.73**	**0.01**
22:5	-		-		-		-		0.57	0.01	**0.57**	**0.01**
22:6	14.44	3.48	4.98	7.75	7.25	4.85	2.60	1.51	4.70	2.55	**6.79**	**4.58**
Tn3	**15.89**	**7.92**	**5.78**	**2.95**	**8.56**	**3.81**	**3.96**	**1.11**	**6.98**	**1.99**	**8.23**	**4.60**
TP	**27.79**	**2.81**	**16.93**	**3.80**	**16.52**	**0.42**	**18.22**	**7.28**	**20.89**	**4.90**	**20.07**	**4.64**
Dry	**7.50**	**2.38**	**8.25**	**3.20**	**10.00**	**3.65**	**8.50**	**5.26**	**7.25**	**4.35**	**8.30**	**3.77**
S:P	**1.18**		**1.99**		**1.89**		**1.90**		**1.72**		**1.74**	
n6:n3	**0.75**		**1.93**		**0.93**		**3.60**		**1.99**		**1.84**	

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.
- = not detected

3.1.3.2 Protein

The results for quantifying protein concentration are shown in Table 10 below. There were no significant differences.

TABLE 10: Protein concentrations of various muscle sites of goat

Goat	Protein concentration g/g
Rump	23.02
Neck	23.19
Midback	22.86
Thigh	22.86
Flank	23.69
Total: MEAN (SD)	**23.13(0.34)**

3.1.3.3 Energy

The results for quantifying energy concentration are shown in Table 11 below. There were no significant differences.

TABLE 11: Energy content of various muscle sites of goat

Goat	Energy content kJ/g
Rump	23.02
Neck	23.19
Midback	22.86
Thigh	22.86
Flank	23.69
Total: MEAN (SD)	**23.13(0.34)**

3.2 Comparison between domestic species

3.2.1 Lipids

The results obtained from quantifying lipid dry weight and fatty acid profiles are shown in Table 12 below.

TABLE 12: Fatty acid profile of domestic species

	PIG		RABBIT		GOAT	
	X	**SD**	**X**	**SD**	**X**	**SD**
TS	**32.99**	3.18	**28.10**	5.03	**33.66**	2.03
TM	**36.40**	2.19	**36.28**	2.35	**47.70**	3.14
18;2	15.62	1.74	18.49	3.52	5.82	1.44
20;4	4.33	1.67	3.35	1.08	3.73	0.94
22;4	0.54	0.06	0.72	0.15	0.69	0.01
22;5	1.04	0.12	1.05	0.13	0.93	0.27
Tn6	**22.62**	2.69	**23.31**	1.84	**11.84**	2.47
18;3	1.13	0.24	1.27	0.27	0.81	0.18
20;5	5.86	8.65	3.78	2.00	0.73	0.01
22;5	1.28	0.18	0.62	0.01	0.57	0.01
22;6	4.09	1.04	9.25	3.88	6.79	4.54
Tn3	**10.74**	7.19	**14.40**	6.05	**8.23**	4.54
TP	**33.36**	8.84	**37.71**	4.46	**20.07**	5.22
Dry	**10.47**	3.66	**14.73**	8.30	**8.30**	3.77
S:P	**1.06**	0.35	**0.77**	0.23	**1.74**	0.36
n6:n3	**2.59**	0.91	**0.63**	0.13	**1.84**	0.65

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.

a) Pig and Rabbit

When comparing total pig to total rabbit, α-docosapentaenoic acid (22:5n3) and n6 fatty acid to n3 fatty acid ratio (n6:n3) was significantly higher in pig ($p=0.0032$ and $p=0.0210$, respectively).

We have shown that a higher concentration of α-docosapentaenoic acid (22:5n3) and n6 fatty acid to n3 fatty acid ratio (n6:n3) is associated with total pig compared to total rabbit.

b) Pig and Goat

Linoleic acid (18:2n6), α-docosapentaenoic acid (22:5n3) and total n6 fatty acids (Tn6) were significantly higher in total pig compared to total goat (p=0.0004, p=0.0027 and p=0.0005, respectively). Total monounsaturated fatty acids (TM) and adrenic acid (22:4n6) were significantly lower in total pig compared to total goat (p=0.0032 and p=0.0039, respectively).

Total pig was found to have a higher linoleic acid (18:2n6), α-docosapentaenoic acid (22:5n3) and total n6 fatty acids (Tn6), and lower total monounsaturated fatty acids (TM) and adrenic acid (22:4n6), when compared to total goat.

c) Rabbit and Goat

Total monounsaturated fatty acids (TM) was significantly lower in total rabbit compared with total goat (p=0.0033). Linoleic acid (18:2n6) was significantly higher in total rabbit compared with total goat (p=0.0012). Total polyunsaturated fatty acids (TP) and total n6 fatty acids (Tn6) was significantly higher in total rabbit compared with total goat (p=0.0054 and p=0.0011 respectively). Alpha-linolenic acid (18:3n3), eicosapentaenoic acid (20:5n3) and alpha-docosapentaenoic acid (22:5n3) were significantly higher in total rabbit compared with total goat (p=0.0412, p=0.252 and p=0.0012, respectively) N6 fatty acid to n3 fatty acid ratio (n6:n3) and saturated fatty acid to polyunsaturated fatty acid ratio (S:P) was significantly lower in total rabbit compared with total goat (p=0.0267 and p=0.0099, respectively).

We have shown that a lower concentration of total monounsaturated fatty acids (TM) was associated with total rabbit when compared to total goat. We have also shown that a higher concentration of linoleic acid (18:2n6), total polyunsaturated fatty acids (TP) and total n6 fatty

acids (Tn6) is associated with total rabbit compared to total goat. Alpha-linolenic acid (18:3n3), eicosapentaenoic acid (20:5n3) and alpha-docosapentaenoic acid (22:5n3)were found to be higher in total rabbit compared to total goat, as opposed to N6 fatty acid to n3 fatty acid ratio (n6:n3) and saturated fatty acid to polyunsaturated fatty acid ratio (S:P) which were found to be lower in total rabbit compared to total goat.

As goat was found to have a higher monounsaturated fat contents than both pig and rabbit, goat may be beneficial in the prevention of CVD. Rabbit has higher polyunsaturated fat content compared to both goat and pig and would therefore decrease the risk of cardiovascular disease as polyunsaturated fats are protective to heart disease. Pig and rabbit both have higher n6 fatty acid contents compared to goat. As N6 has been shown to decrease the risk of CVD, a higher N6 content would be beneficial.

3.2.2 Protein

The results for quantifying protein concentration are shown in Table 13 below. There were no significant differences.

TABLE 13: Protein concentrations of various muscle sites of domestic species

	Pig	Rabbit	Goat
Rump	23.26	22.50	23.02
Neck	21.74	26.73	23.19
Midback	21.50	22.53	22.86
Thigh	22.44	22.15	22.86
Flank	22.53	26.31	23.69
Total: MEAN (SD)	**22.29(0.70)**	**24.04(2.27)**	**23.13(0.34)**

Data expressed as g/g

TABLE 14: Comparison of the statistical variation between protein concentrations in domestic species. There were no significant differences.

	PIG	RABBIT	GOAT
PIG	-	ns	ns
RABBIT	ns	-	ns
GOAT	ns	ns	-

3.2.3 Energy

The results for quantifying energy concentration are shown in Table 15 below. There were no significant differences.

TABLE 15: Energy content of various muscle sites of domestic species

	Pig	Rabbit	Goat
Rump	1.72	1.41	1.80
Neck	1.78	1.28	1.43
Midback	1.71	1.66	1.95
Thigh	1.61	1.88	1.64
Flank	1.98	1.58	2.03
Total: MEAN (SD)	**1.76 (0.14)**	**1.56 (0.23)**	**1.77 (0.24)**

Data expressed as kJ/g

TABLE 16: Comparison of the statistical variation between energy content in domestic species

	PIG	RABBIT	GOAT
PIG	-	ns	ns
RABBIT	ns	-	ns
GOAT	ns	ns	-

3.3 Individual Wild Species

3.3.1 Impala

Two impala were obtained from a farm in Lichtenburg. Samples were taken from five sites throughout the body, i.e. rump, neck, midback, thigh and flank. These samples were used for lipid, protein and energy analysis. As lipid analysis was the main focus of this research, samples for this was a priority. Protein and energy analysis was performed on whatever samples were available although, in most cases only one sample was available and therefore, statistical analysis was impractical.

3.3.1.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 17 below.

Total n3 fatty acids (Tn3) was significantly lower in impala rump compared to impala thigh ($p=0.042$) and saturated fatty acid to polyunsaturated fatty acid ratio (S:P) was significantly higher in impala rump compared to impala thigh ($p=0.043$). When comparing impala rump to impala flank, arachidonic acid (20:4n6) was significantly lower in impala rump ($p=0.034$), total n3 fatty acids (Tn3) was significantly higher in impala rump ($p=0.034$) and n6 fatty acid to n3 fatty acid ratio (n6:n3) was significantly lower in impala rump ($p=0.017$). Total saturated fatty acid (TS) was significantly higher in impala neck compared to impala midback ($p=0.013$) and linoleic acid (18:2n6) was significantly lower in impala neck compared to impala midback ($p=0.039$). Saturated fatty acid to polyunsaturated fatty acid ratio (S:P) was significantly higher in impala midback compared with impala thigh ($p=0.032$). Total saturated fatty acid (TS) was significantly lower in impala midback compared to impala flank ($p=0.030$) and docosahexaenoic acid (22:6n3) was significantly higher in impala midback compared to

impala flank (p=0.044). When comparing impala thigh to impala flank, α-docosapentaenoic acid (22:5n3) was significantly lower (p=0.025), total n3 fatty acids (Tn3) was significantly higher (p=0.037) and n6 fatty acid to n3 fatty acid ratio (n6:n3) was significantly lower (p=0.031) in impala thigh.

A lower concentration of total n3 fatty acids (Tn3) and a higher saturated fatty acid to polyunsaturated fatty acid ratio (S:P) was associated with impala rump compared to impala thigh. When comparing impala rump to impala flank, we found that impala rump had a lower arachidonic acid (20:4n6) content and n6 fatty acid to n3 fatty acid ratio (n6:n3), and a higher total n3 fatty acids (Tn3) content. When comparing impala neck compared to impala midback, total saturated fatty acid (TS) concentration was higher in impala neck and linoleic acid (18:2n6) concentration was lower in impala neck. Saturated fatty acid to polyunsaturated fatty acid ratio (S:P) was found to be higher in impala midback compared with impala thigh. Total saturated fatty acid (TS) concentration was lower in impala midback compared to impala flank and docosahexaenoic acid (22:6n3) concentration was higher in impala midback compared to impala flank. When comparing impala thigh to impala flank, the concentration of α-docosapentaenoic acid (22:5n3) and the n6 fatty acid to n3 fatty acid ratio (n6:n3) was lower, and the concentration of total n3 fatty acids (Tn3) was higher in impala thigh.

Impala thigh when compared to impala rump, impala rump when compared to impala flank, and impala thigh when compared to impala flank, were higher in n3 fatty acid and are therefore recommended for the prevention of CVD. Both impala neck and impala flank have higher saturated fatty acid contents than impala midback. Impala neck and impala flank should therefore be avoided as saturated fats promote CVD.

TABLE 17: Fatty acid profile of various muscle sites of impala

	RUMP		NECK		MIDBACK		THIGH		FLANK		TOTAL	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
TS	**31.44**	**7.89**	**32.34**	**7.76**	**29.55**	**6.79**	**29.02**	**5.99**	**34.51**	**6.86**	**31.37**	**2.22**
TM	**17.21**	**4.87**	**18.50**	**6.96**	**16.73**	**5.35**	**16.51**	**4.56**	**17.63**	**6.47**	**17.32**	**0.79**
18:2	16.48	1.42	14.86	3.17	19.35	2.78	16.10	11.72	15.90	3.10	**16.54**	**1.68**
20:4	8.65	0.23	8.72	1.95	8.75	4.79	9.41	2.80	11.08	0.41	**9.32**	**1.03**
22:4	0.61	0.01	0.81		-		-		0.86	0.31	**0.76**	**0.01**
22:5	2.25	0.11	2.37	0.12	2.49	1.59	2.57	0.63	2.74	0.44	**2.49**	**0.19**
Tn6	**28.00**	**7.21**	**32.76**	**5.58**	**31.23**	**8.44**	**28.78**	**7.02**	**34.98**	**6.29**	**31.15**	**2.86**
18:3	3.56	1.75	3.27	1.67	3.25	1.13	3.47	1.50	2.60	0.01	**3.23**	**0.38**
20:5	4.20	0.42	4.29	0.98	5.00	2.34	10.97	1.88	6.00	6.42	**6.09**	**0.01**
22:5	1.67	1.01	1.33	0.73	1.73	0.43	1.64	0.92	1.83	0.51	**1.64**	**0.01**
22:6	12.49	0.84	9.39	2.92	11.85	4.57	11.11	5.14	5.18	4.21	**10.01**	**2.94**
Tn3	**23.05**	**4.59**	**19.27**	**3.38**	**22.83**	**4.35**	**28.46**	**4.95**	**16.74**	**2.13**	**22.07**	**4.43**
TP	**51.05**	**3.50**	**52.03**	**9.53**	**54.06**	**5.94**	**57.24**	**0.22**	**51.72**	**12.90**	**53.22**	**2.51**
Dry	**7.50**	**0.71**	**4.00**	**0.41**	**5.50**	**0.71**	**6.50**	**2.12**	**5.50**	**0.71**	**5.80**	**0.93**
S:P	**0.62**		**0.62**		**0.55**		**0.51**		**0.67**		**0.59**	
n6:n3	**1.21**		**1.70**		**1.37**		**1.01**		**2.09**		**1.48**	

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.
- = not detected

3.3.1.2 Protein

The results for quantifying protein concentration are shown in Table 18 below. There were no significant differences.

TABLE 18: Protein concentrations of various muscle sites of impala

Impala	Protein concentration g/g
Rump	2.19
Neck	1.31
Midback	1.80
Thigh	2.16
Flank	2.43
Total: MEAN (SD)	**1.98(0.44)**

3.3.1.3 Energy

The results for quantifying energy concentration are shown in Table 19 below. There were no significant differences.

TABLE 19: Energy content of various muscle sites of impala

Impala	Energy content kJ/g
Rump	21.93
Neck	21.76
Midback	21.97
Thigh	21.84
Flank	22.05
Total: MEAN (SD)	**21.91(0.11)**

3.3.2 Wildebeest

Two wildebeest were obtained from a farm in Lichtenburg. Samples were taken from five sites throughout the body, i.e. rump, neck, midback, thigh and flank. These samples were used for lipid, protein and energy analysis. As lipid analysis was the main focus of this research, samples for this was a priority. Protein and energy analysis was performed on whatever samples were available although, in most cases only one sample was available and therefore, statistical analysis was impractical.

3.3.2.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 20 below.

When comparing wildebeest rump to wildebeest neck, n6 fatty acid to n3 fatty acid ratio (n6:n3) was significantly lower in wildebeest rump ($p=0.015$). Total monounsaturated fatty

acids (TM) and total n3 fatty acids (Tn3) was significantly lower in wildebeest rump when compared to wildebeest flank (p=0.019 and p=0.015 respectively). Total polyunsaturated fatty acids (TP) was significantly lower in wildebeest neck compared to wildebeest flank (p=0.030). γ-Docosapentaenoic acid (22:5n6) was significantly higher in wildebeest midback compared to wildebeest thigh (p=0.029). Total saturated fatty acids (TS) was significantly lower in wildebeest midback compared to wildebeest flank (p=0.038).

When we compared wildebeest rump to wildebeest neck, we found that the wildebeest rump had a lower n6 fatty acid to n3 fatty acid ratio (n6:n3). Total monounsaturated fatty acids (TM) and total n3 fatty acids (Tn3) was found to be lower in wildebeest rump when compared to wildebeest flank. Wildebeest neck was found to have a lower total polyunsaturated fatty acids (TP) content when compared to wildebeest flank.

When comparing wildebeest midback to wildebeest thigh and flank, there was a higher γ-docosapentaenoic acid (22:5n6) concentration, and a lower total saturated fatty acids (TS) concentration in wildebeest midback respectively.

Wildebeest flank has a higher n3 fatty acid content than wildebeest rump, and a higher polyunsaturated fat content than wildebeest neck. This should indicate that wildebeest flank should therefore be a cut of preference as n3 fatty acids and polyunsaturated fats are known to decrease the risk of CVD but, wildebeest flank has a saturated fat content higher than wildebeest midback and this saturated fat increases the risk of CVD.

TABLE 20: Fatty acid profile of various muscle sites of wildebeest

	RUMP		NECK		MIDBACK		THIGH		FLANK		TOTAL	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
TS	**28.92**	**6.46**	**32.77**	**7.35**	**24.78**	**5.87**	**27.21**	**5.22**	**25.77**	**5.20**	**27.89**	**3.14**
TM	**17.41**	**3.01**	**17.97**	**3.02**	**19.96**	**5.11**	**25.19**	**5.72**	**17.61**	**3.13**	**19.63**	**3.27**
18:2	18.45	0.01	17.69	13.04	19.05	3.28	17.94	11.15	19.71	0.02	**18.57**	**0.82**
20:4	12.60	1.79	12.47	7.65	12.81	3.41	12.75	6.65	13.64	1.11	**12.86**	**0.46**
22:4	1.18	0.09	2.24	0.77	0.76	0.01	0.71	0.01	0.80	0.01	**1.14**	**0.01**
22:5	2.80	0.33	2.95	1.74	3.71	0.86	3.05	2.02	3.29	0.42	**3.16**	**0.35**
Tn6	**35.03**	**8.20**	**35.93**	**7.49**	**36.33**	**8.39**	**34.46**	**8.12**	**37.45**	**8.86**	**35.84**	**1.16**
18:3	4.05	0.43	4.77	2.56	4.26	1.56	3.80	1.91	4.34	0.54	**4.24**	**0.36**
20:5	-		-		-		-		-		**-**	
22:5	0.71	0.18	0.96	0.37	1.07	0.41	0.72	0.46	0.78	0.14	**0.85**	**0.01**
22:6	10.91	5.24	6.69	4.01	10.56	1.89	4.08	6.13	11.54	5.79	**8.76**	**3.23**
Tn3	**17.40**	**4.59**	**13.57**	**2.81**	**17.65**	**4.32**	**10.24**	**1.64**	**18.51**	**4.84**	**15.47**	**3.49**
TP	**52.43**	**12.46**	**49.51**	**15.81**	**53.98**	**13.21**	**44.70**	**17.13**	**55.95**	**13.39**	**51.31**	**4.39**
Dry	**11.50**	**12.02**	**6.00**	**4.24**	**5.00**	**1.41**	**5.00**	**1.41**	**3.00**	**0.00**	**6.10**	**6.44**
S:P	**0.55**		**0.66**		**0.46**		**0.61**		**0.46**		**0.55**	
n6:n3	**2.01**		**2.65**		**2.06**		**3.37**		**2.02**		**2.42**	

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.
- = not detected

3.3.2.2 Proteins

The results for quantifying protein concentration are shown in Table 21 below. There were no significant differences.

TABLE 21: Protein concentrations of various muscle sites of wildebeest

Wildebeest	Protein concentration g/g
Rump	1.53
Neck	1.70
Midback	1.54
Thigh	1.76
Flank	2.17
Total: MEAN (SD)	**1.74(0.26)**

3.3.2.3 Energy

The results for quantifying energy concentration are shown in Table 22 below. There were no significant differences.

TABLE 22: Energy content of various muscle sites of wildebeest

Wildebeest	Energy content kJ/g
Rump	20.63
Neck	21.63
Midback	21.61
Thigh	21.63
Flank	21.42
Total: MEAN (SD)	**21.38(0.43)**

3.3.3 Springbok

Fortunately a lone springbok, from a farm in Lichtenburg, became available. As there was only one, statistical analysis could not be performed.

3.3.3.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 23 below.

A total springbok lipid profile was established using the individual muscle samples (i.e. Rump, neck, midback, thigh and flank) in order to establish a mean and standard deviation.

TABLE 23: Fatty acid profile of various muscle sites of springbok

	RUMP		NECK		MIDBACK		THIGH		FLANK		TOTAL	
	X	SD	X	SD	X	SD	X	SD	X	SD	X	SD
TS	**41.94**	**9.70**	**44.14**	**9.99**	**39.89**	**9.49**	**36.61**	**8.49**	**44.34**	**10.28**	**41.38**	**3.23**
TM	**44.81**	**19.67**	**41.22**	**16.59**	**29.35**	**15.83**	**40.98**	**17.88**	**39.04**	**15.10**	**39.08**	**5.83**
18:2	6.40		7.04		16.22		6.64		7.79		**8.82**	**4.17**
20:4	1.47		1.15		3.86		4.96		1.83		**2.65**	**1.66**
22:4	-		-		-		-		-		**-**	
22:5	-		-		1.04		-		-		**1.04**	**0.01**
Tn6	**7.88**	**3.49**	**8.19**	**4.16**	**21.11**	**8.07**	**11.60**	**1.19**	**9.62**	**4.21**	**11.68**	**5.47**
18:3	2.26		2.98		4.89		2.21		2.52		**2.97**	**1.12**
20:5	-		0.89		1.52		-		0.67		**1.02**	**0.01**
22:5	-		-		-		-		0.59		**0.59**	**0.01**
22:6	-		-		0.74		0.57		0.52		**0.61**	**0.12**
Tn3	**2.26**	**0.01**	**3.87**	**1.48**	**7.71**	**2.02**	**8.58**	**2.67**	**4.29**	**0.97**	**5.34**	**2.69**
TP	**10.13**	**3.98**	**12.06**	**3.06**	**28.83**	**9.48**	**20.18**	**2.13**	**13.91**	**3.77**	**17.02**	**7.60**
Dry	**17.00**		**8.00**		**7.00**		**11.00**		**5.00**		**9.60**	**4.67**
S:P	**4.14**		**3.66**		**1.38**		**1.81**		**3.19**		**2.84**	
n6:n3	**3.49**		**2.12**		**2.74**		**1.35**		**2.24**		**2.39**	

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.
- = not detected

3.3.3.2 Proteins

The results for quantifying protein concentration are shown in Table 24 below.

TABLE 24: Protein concentrations of various muscle sites of springbok

Springbok	Protein concentration g/g
Rump	2.27
Neck	2.35
Midback	3.57
Thigh	2.57
Flank	
Total: MEAN (SD)	**2.69(0.60)**

3.3.3.3 Energy

The results for quantifying energy concentration are shown in Table 25 below.

TABLE 25: Energy content of various muscle sites of springbok

Springbok	Energy content kJ/g
Rump	23.02
Neck	25.35
Midback	23.17
Thigh	22.47
Flank	
Total: MEAN (SD)	**23.50(1.27)**

3.4 Comparison between Wild Species

As only one springbok was available, comparison between springbok and other wild species (impala and wildebeest) was not performed.

3.4.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 26 below.

a) Impala and Wildebeest

When comparing total impala to total wildebeest, arachidonic acid (20:4n6) was found to be lower in total impala (p=0.0472). Gamma -docosapentaenoic acid (22:5n6) was found to be higher in total impala (p=0.0460).

When we compared total impala to total wildebeest, arachidonic acid (20:4n6) was lower in total impala, while gamma-docosapentaenoic acid (22:5n6) was higher in total impala.

TABLE 26: Fatty acid profile of wild species

	IMPALA		WILDEBEST	
	X	**SD**	**X**	**SD**
TS	**31.37**	2.22	**27.89**	3.14
TM	**17.32**	0.79	**19.63**	3.27
18;2	16.54	1.68	18.57	0.82
20;4	9.32	1.03	12.86	0.46
22;4	0.76	0.13	1.14	0.64
22;5	2.49	0.19	3.16	0.35
Tn6	**31.15**	2.86	**35.84**	1.16
18;3	3.23	0.38	4.24	0.36
20;5	6.09	2.82	-	
22;5	1.64	0.19	0.85	0.16
22;6	10.01	2.94	8.76	3.23
Tn3	**22.07**	4.43	**15.47**	3.49
TP	**53.22**	2.51	**51.31**	4.39
Dry	**5.80**	0.93	**6.10**	6.44
S:P	**0.59**	0.06	**0.55**	0.09
n6:n3	**1.48**	0.42	**2.42**	0.59

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.
- = not detected

3.4.2 Proteins

The results for quantifying protein concentration are shown in Table 27 below.

TABLE 27: Protein concentrations of various muscle sites of wild species

	Impala	**Wildebeest**
Rump	2.19	1.53
Neck	1.31	1.70
Midback	1.80	1.54
Thigh	2.16	1.76
Flank	2.43	2.17
Total: MEAN (SD)	**1.98(0.44)**	**1.74(0.26)**

TABLE 28: Comparison of the statistical variation between protein concentrations in wild species

	WILDEBEEST
IMPALA	ns

3.4.3 Energy

The results for quantifying energy concentration are shown in Table 29 below.

TABLE 29: Energy content of various muscle sites of wild species

	Impala	Wildebeest
Rump	21.93	20.63
Neck	21.76	21.63
Midback	21.97	21.61
Thigh	21.84	21.63
Flank	22.05	21.42
Total: MEAN (SD)	**21.91(0.11)**	**21.38(0.43)**

TABLE 30: Comparison of the statistical variation between energy content in wild species

	WILDEBEEST
IMPALA	*

*=significant difference

Significant differences were found between total impala energy content and total wildebeest energy content, with impala total energy being higher than wildebeest energy.

3.5 Comparison of Domestic and Wild Species

3.5.1 Lipids

The results from quantifying lipid dry weight and fatty acid profiles are shown in Table 31 below.

When comparing the domestic species (i.e. pig, rabbit and goat) to the wild species (i.e. impala and wildebeest) total monounsaturated fatty acids (TM) was significantly higher in the domestic species as compared to impala and wildebeest ($p=0.0384$). Arachidonic acid (20:4n6), adrenic acid (22:4n6) and gamma-docosapentaenoic acid (22:5n6) were also found

to be significantly higher in the domestic species when compared to impala and wildebeest (p=0.0316, p=0.0357 and p=0.0256, respectively)

TABLE 31: Fatty acid profile of domestic and wild species

	DOMESTIC		WILD	
	X	**SD**	**X**	**SD**
TS	**31.58**	3.04	**17.31**	20.19
TM	**40.13**	6.56	**23.34**	23.74
18;2	13.31	6.64	9.98	4.71
20;4	3.80	0.50	2.15	2.34
22;4	0.65	0.10	0.37	0.39
22;5	1.01	0.07	0.54	0.67
Tn6	**19.26**	6.43	**12.85**	9.07
18;3	1.07	0.24	0.65	0.59
20;5	3.46	2.58	3.02	0.62
22;5	0.82	0.40	0.61	0.30
22;6	6.71	2.58	4.65	2.92
Tn3	**11.12**	3.10	**7.11**	5.67
TP	**30.38**	9.19	**19.79**	14.98
Dry	**11.17**	3.27	**5.95**	0.21
S:P	**1.19**	0.50	**0.84**	0.49
n6:n3	**1.69**	0.99	**1.34**	0.49

Data expressed as FAME percent total, except 'Dry' which is mg lipid/g wet mass.

3.5.2 Protein

The results for quantifying protein concentration are shown in Table 32 below.

TABLE 32: Protein analysis of domestic and wild species

	Domestic	Wild
Rump	1.64	1.48
Neck	1.49	1.00
Midback	1.78	1.43
Thigh	1.71	1.58
Flank	1.86	1.75
Total: MEAN (SD)	**1.70(0.14)**	**3.29(0.28)**

Total reported as mean(standard deviation)

TABLE 33: Comparison of the statistical variation between protein concentrations in domestic and wild species

	WILD
DOMESTIC	*

* = significant difference

Significant differences were found between total domestic protein (i.e. an average of total pig, rabbit and goat) and total wild protein (i.e. an average of total impala and wildebeest) with domestic protein being significantly lower than wild protein 1 ($p=0.0009$).

3.5.3 Energy

The results for quantifying energy concentration are shown in Table 34 below.

TABLE 34: Energy analysis of domestic and wild species

	Domestic	Wild
Rump	22.93	21.28
Neck	23.89	21.69
Midback	22.29	21.79
Thigh	22.49	21.74
Flank	24.18	21.73
Total: MEAN (SD)	**23.15(0.84)**	**21.65(0.21)**

Total reported as mean(standard deviation)

TABLE 35: Comparison of the statistical variation between energy concentrations in domestic and wild species

	WILD
DOMESTIC	*

* = significant difference

Significant differences were found between total domestic energy (i.e. an average of total pig, rabbit and goat) and total wild energy (i.e. an average of total impala and wildebeest), with domestic energy being significantly higher than wild energy ($p=0.0399$).

The finding that wild species show higher protein levels, while domestic species show greater energy storage levels is consistent with the observation that domestic species have been shown to store greater amounts of fat in the muscle tissues (marbling effects) (Crawford, 1968).

4. General Discussion

In 1968, Crawford established that there was a striking difference in tissue fatty acid profiles when comparing wild (free-living ruminants) and domestic (bovine) species (species not specified). He showed that there were very low total fat levels in wild game meat (less than 2%), while in domesticated meats, even with all visible fat removed, total fat was still around 5%. Crawford also showed that domesticated meat had a high percentage of saturated fat, both invisibly in the muscle fibres themselves (in the phosphoglyceride fractions of the cell membranes) as well as visibly in the form of the marbling effects (deposition of triacylglycerols in interfascicular adipocytes, i.e. between muscle fibres). Conversely, domesticated meat was very low in PUFA with only 2% of the total fatty acids being polyunsaturated. Wild game, on the other hand, was found to be very low in saturated fat, whilst wild game was comparatively high in PUFA (30%), although with little long-chain PUFA (Crawford, 1968). In 1970 Crawford reported on further studies and found high levels of both linoleic and α-linolenic acid present in wild game. When comparing the adipose tissue, around the lean meat, between wild and domestic meats, it was found that wild game adipose tissue consisted primarily of phosphoglycerides and contained little triacylglycerols (Crawford, 1968; Crawford et al, 1970; Sinclair, and O'Dea,1991), resulting in wild game having little stored energy in the muscle itself. The comparison between wild and domestic adipose tissue indicates that marbling, occurring in domestic meat, is associated with an increase in fatty acid infiltration (Crawford, 1968; Crawford et al, 1970).

Similar comparative studies have been done in Australia, the United Kingdom and the United States of America to determine the fatty acid profiles of their local wild game meats. These studies showed that wild game meats had decreased saturated fat and increased

polyunsaturated fat levels when compared to domestic meats (Cordain *et al*, 2002; Crawford *et al*, 1970; Mann *et al*, 1995; Sanders *et al*, 1994).

A possible explanation for the differences in fat content of domesticated meat versus wild game is a combination of genetics, selective breeding, management practices and readily available food, resulting in obese domesticated animals showing the large amount of visible fat seen in these animals. It has also been established that the leaner the meat, the lower the saturated fat content and therefore the lesser the impact on the risk of CVD in humans consuming that meat (Sanders et al, 1994). A recent study by Cordain *et al* (2002) showed significant differences in muscle lipid and fatty acid composition between wild game and domestic meats. In their study they also indicated that these differences demonstrated that wild game, with its associated decreased total fat and increased PUFAs, is favourable for the prevention and reduction of CVD and other chronic diseases in humans (Cordain *et al*, 2002).

Although our study did not take slaughter weight (the weight of the animal at the time of slaughtering) into consideration, as this data was not available, it has been shown to significantly influence intramuscular fat content in pigs. An increase in slaughter weight results in an increase in intramuscular fat, a decrease in total phosphoglyceride content of intramuscular fat, and a decrease in linoleic acid and docosahexanoic acid within the phosphoglyceride fractions (Hugo, Osthoff, Jooste, 1999).

Comparative studies between the local wild and domestic meats in both Australia and the United Kingdom showed significant differences favouring human consumption of wild meats. Crawford (1968) showed lower total fat content (less than 2%) in wild game meat as compared to domesticated meats (5%). Saturated fat was found to be lower in wild meat as

compared to domestic meat and polyunsaturated fat was seen to be higher in wild meat as compared to domestic meats (Cordain et al, 2002; Crawford, 1970; Mann et al, 1995; Sinclair, 1991). The differences between the wild and domestic meat profiles reported in these studies can mainly be attributed to the intense agricultural practices applied to the domestic species.

This study has shown only minimal differences between wild and domestic meats, in contrast to the studies reported from elsewhere, and our pilot study. This may reflect that the domesticated species analysed do not selectively deposit significant amounts of saturated fatty acids in the form of triacylglycerols in their muscle tissues. Alternatively, the particular individual specimens were not from commercial sources, as samples were preferred immediately post mortem, and thus were obtained from the Central Animal Service of this University. In this facility animals are fed appropriate amounts of food and not subjected to intensive agricultural practices (predominantly minimal exercise and increased food intake), and hence may have avoided the impact of this practice. In the pilot study, using commercially obtained samples of domestic species, there were differences detected between wild and domestic species, but not to the same degree as reported in studies elsewhere. At the same time, in South Africa, our agriculture may be less intense therefore resulting in smaller differences between our wild and domestic meats. In support of this possibility, this study has shown a mean of ±10mg lipid/g wet mass of tissue, compared with a mean of ±20mg lipid/g wet mass of tissue in the pilot study, when analysing pig. In contrast, figures published by the United Kingdom Ministry of Agriculture, Fisheries and Foods and Medical Research Council report a mean of ±70mg lipid/g wet mass of tissue (McCance and Widdowson, 1978).

The comparatively lower levels of total lipid detected in the pig samples from the University of Witwatersrand Central Animal Service versus those from the commercial samples in the pilot study may also indicate that it would be feasible to avoid the effects of domestication on meat lipid levels, merely by reverting to more extensive farming practices, but the commercial implications of such a change in farming practice may be significant. However, given the apparent less intensive nature of South African farming practice, this might not be such a massive step, and might reduce the impact of meat lipids on human health as well as distinctly improving the public image of domesticated meat and obviating any necessity to change to farming wild species.

This study has shown that a lower total energy content is associated with wildebeest when compared to impala. Total domestic energy content (i.e. an average of pig, rabbit and goat) was found to be higher than total wild energy content (i.e. an average of impala, wildebeest and springbok), (Refer to Table 31 and Table 35).

A lower protein concentration was associated with total domestic protein (i.e. an average of total pig, rabbit and goat) when compared to total wild protein 1 (i.e. an average of total impala, wildebeest and springbok) (Refer to Table 28 and Table 29).

As no major differences in protein or energy were found between wild and domestic meats, selection of meat type and cut should be mainly based on the lipid profile, as well as personal preference for a particular meat as it has been established that the content of the various fats is the key indicator in the prevention of CVD. As only few samples were available for protein and energy testing, further experimentation is needed before any absolute conclusions can be drawn.

Previously it has been shown that there is no significant difference in muscle-protein amino acid composition from wild game as compared with domesticated meat, so a change from one to the other would not adversely impact on protein availability (Crawford, 1968; Crawford *et al*, 1970).

Thus the differences demonstrated, even though largely not significant, between wild and domestic meats in respect of their fat content and fatty acid profiles is not paralleled by differences in the energy or protein levels. Thus the differences reflect changes in quality rather than quantity.

It was decided to focus on the species chosen for this study as little work had been done on them previously. Cattle and sheep have not been included in this study as a large number of studies have previously looked at both of these species (McCance and Widdowson, 1978) and, as indicated above, it was not possible to obtain samples immediately post mortem and from the body sites chosen within the time frame of this study. Also, as there are a number of varieties of cattle and sheep farmed in South Africa, it was beyond the scope of this study to examine all of them, and to merely select and sample one variety would not necessarily be representative of all varieties.

5. Conclusion

In this study, no consistent differences could be demonstrated between wild and domestic South African meats. Whilst there are significant differences between the protein and energy values between wild and domestic meats, the differences are not large and are of doubtful dietary significance. There are, however, significant dietary differences between individual wild and domestic South African species from the point of view of lipid and fatty acid composition but no consistent pattern of variation was seen. It may have improved the study if more samples from seasonally variant individuals were available; however this was not possible within the time constraints and sampling availability of this study. This difficulty can be seen by the fact that only one springbok was available for analysis. Without more data it is difficult to come to any conclusion as far as recommending, or not, any particular cut of meat. No absolute recommendations, therefore, can be made as to which individual wild or domestic meat one should consume but rather a recommendation to be selective to the type (species and cut) of meat chosen for consumption on the basis of data presented both here (for example a higher polyunsaturated fatty acid content and a lower saturated fatty acid content - pig thigh and wildebeest midback) and elsewhere as well as personal preference.

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