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Carcass composition comparison of male and female red deer and hybrids with Père David's deer

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Abstract The carcass composition of male and female red deer and 1/4 Père David's deer hybrids were compared. Males had significantly more total carcass muscle and total carcass bone ($P < 0.01$), but significantly less total carcass fat and intramuscular fat in the *longissimus dorsi* ($P < 0.01$) than females when compared at the regressed mean hot carcass weight of 72.9 kg (19–20 months of age). Genotype differences were significant for muscle distribution with hybrids having relatively more muscle in the hind leg primal cut compared with red deer. Gender differences in muscle, bone, and fat tissue distribution were also evident with males having relatively more fat and bone in the neck and shoulder primal cuts. Père David's deer hybrids have significantly different muscle tissue distribution than red deer, which may be indicative of a major gene effect similar to double-muscling observed in cattle and callipyge in sheep.

Keywords Père David's deer; red deer; gender; genotype; carcass comparison; tissue partitioning

INTRODUCTION

Many deer species were introduced into New Zealand between 1861 and 1910 (Challies 1985), including the Scottish red deer (*Cervus elaphus scoticus*) which forms the base resource from which deer farming in New Zealand has developed (Yerex 1982). Red deer differ markedly from Père David's deer (*Elaphurus davidianus*, PD) in terms of seasonality (breeding cycle is about three months earlier in PD (Loudon et al. 1989)) and mature size (PD females are about 70% larger). There are also differences between these species in their behaviour (Altmann & Scheel 1980), morphology (Wemmer 1983), and disease resistance (Orr & Mackintosh 1988).

Despite the large differences in seasonality between these two species, small numbers (n = 20) of the interspecies hybrids between PD stags and red deer hinds have been generated using artificial insemination (AI) techniques (Asher et al. 1988; Fennessy & Mackintosh 1992). Subsequently, these F_1 hybrids were used in AI ((PD×R)×R) and multiple ovulation and embryo transfer programs (MOET) to generate 1/4 Père David's / 3/4 red deer backcross hybrids (Goosen et al. 1997; Tate et al. 1997). This study compared and contrasted carcass characteristics and growth of male and female red deer and 1/4 Père David's/ 3/4 red deer backcross hybrids fed individually in an indoor environment. The purpose of these comparisons was to evaluate total carcass muscle, bone, and fat as well as the differences in the distribution of these tissues between genotypes and genders.

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MATERIALS AND METHODS

General experimental details

Genotype and gender differences in carcass characteristics were quantified in a total of 24 deer comprising seven 1/4 Père David's / 3/4 red deer hybrids (hybrid) and five red deer (red) of each gender born in late spring (average birth date was 13 November 1992). The animals were individually housed in indoor pens at 28–34 weeks of age (April 1993) for 55 weeks to June 1994. Pens allowed for visual contact with deer in the adjacent pens (2.8 m × 1.7 m and 2.2 m × 1.1 m for males and females, respectively).

The animals were fed a barley-based pelleted diet (Table 1) *ad libitum* (11.7 ± 0.20 (mean ± SD) MJ ME kg^{-1}) and chaffed lucerne hay (9.1 ± 0.6 MJ ME kg^{-1}). The latter was fed at approximately 0.5 kg per 10 kg of concentrate with unrestricted access to water. All animals were offered feed at 1.1 to 1.2 times their expected intake three times per week. Expected intake was based on previous two weeks' intake. Feed bins were checked daily to ensure that food supply was *ad libitum* and residues were removed weekly. Samples of all feeds and individual animal residues were taken weekly.

All animals were allowed to exercise together twice weekly in a 14 m × 14 m outdoor pen with water but no feed. During the rut, males and females were exercised separately to avoid pregnancies. During the experiment three animals died of or were euthanased after contracting the fatal malignant catarrhal fever (MCF) virus (Orr & Mackintosh 1988). These included two hybrid females (one at 5 weeks and one at 20 weeks; data not included) and a red male (at 54 weeks; data included). The deer were slaughtered at a commercial deer slaughter plant using standard New Zealand procedures on 27 June 1994 at 19 to 20 months of age.

Slaughter and dissection procedures

Data collected at slaughter included hot carcass weight (HCW) and the weights of the combined kidney, knob, and channel fat depots (KKCF). Hot carcass weight for all animals was measured prior to carcasses being split down the spine. The left half carcasses were retained for measurements. Half carcasses were cut into five primal cuts, neck, shoulder, rib, loin, and hind leg, and immediately frozen. The neck included the section from the 2nd cervical vertebrae to the 3rd rib; the shoulder included the scapula and fore limb which was removed from the neck primal in one piece; the rib included the section from the 4th rib to the 12th rib; the hind leg included from the caudal end of the carcass to 1.5 vertebrae forward of the last fused sacral vertebrae; the loin included the remaining 9-rib section in the centre of the carcass. Prior to freezing, GR (mm) and EMA area (cm^2) were measured using the loin cut. Specifically, GR was measured as the tissue depth in millimetres over the 12th rib at a point 16 cm from the midline and eye muscle area was measured as the area in square centimetres at the 12th rib (including the *multifidus* muscle).

After thawing, these cuts were divided into muscle, bone, and fat components using a butcher's dissection technique, and individual components were weighed. In addition, individual shoulder and hind leg muscles were dissected out and weighed. The shoulder muscles included *deltoideus*, *supraspinatus*, *infraspinatus*, and *biceps brachii*, and the hind leg muscles included *gluteus*, *vastus*, *rectus femoris*, *semimembranosus*, *semitendinosus*,

Table 1 Composition of the pelleted diet fed to 1/4 Père David's / 3/4 red deer hybrids and red deer. The vitamin and mineral mix contained 25 g kg^{-1} dicalcium phosphate, 2500 iu kg^{-1} Vitamin A, 1000 iu kg^{-1} Vitamin 3, 10 iu kg^{-1} Vitamin E, and 0.15 mg kg^{-1} of selenium as sodium selenate. Broll is a 50/50 mix of bran and pollard.

Component	%	Component	%
Barley	48.5	Sodium bentonite	2.0
Broll	20.5	Crystallised lime	1.5
Rapeseed meal	7.5	Zeolite	1.0
Peas	7.5	Salt (NaCl)	1.0
Extracted cottonseed meal	4.0	Molasses	1.0
Oat husks	2.5	Urea	1.0
Fishmeal	2.0	Vitamins and minerals	0.25

and *gastrocnemius*. The *gluteus* included the middle, accessory, and deep *gluteus* muscles, and the *vastus* included the *lateralis*, *intermedius*, and *medialis*.

Moisture loss which occurred between the thawed weight and cold primal weight was attributed to muscles as a proportion of primal total muscle weight (average loss was 2.2%). The sum of the dissected components was compared with the original primal cut weight to measure tissue loss during dissection. Muscle and fat were proportionally adjusted to account for the loss during dissection (average loss 2.6%); no loss from bone during dissection was assumed. Thus, these procedures corrected from dissected weights up to a cold primal weight. Cold side weight was then adjusted to a HCW equivalent, partitioning the weight loss between muscle, bone, and fat components proportionally by weight.

Intramuscular fat percentages for the *longissimus dorsi* and *semimembranosus* were determined using the appropriate ether extraction procedure (Pettinati et al. 1973) using triplicate 50-g subsamples of mid-muscle minced tissue.

After dissection, 25-mm strips of *l. dorsi* from the caudal end at the 12th rib and *semimembranosus* from the centre of the muscle were measured for muscle shear force using standard techniques (Stevenson et al. 1992). A Meat Industry Research Institute of New Zealand (MIRINZ) tenderometer (Salmond Smith Biolab, Christchurch, New Zealand) was used to measure the pressure (kPa) required to shear 1-cm cubes when cut across the grain. This was subsequently converted to a shear force (kg) using the calibration formula specific to the instrument.

Statistical analysis

The data were analysed to assess the effect of gender and genotype on carcass composition using the allometric function $y = ax^b$ after log transformation to minimise the correlation between the means and the variances.

Using generalised linear models (SAS 1989), gender and genotype were fitted as fixed effects. Genotype and gender effects on total carcass muscle, bone, and fat were analysed using HCW as the covariate. HCW was chosen as the preferred basis for comparisons between genotypes as this is the main criterion used for valuing carcasses in the deer industry. Genotype and gender effects on muscle, bone, and fat distribution were analysed using total muscle (TM), total bone (TB), and total fat (TF) as the covariates, respectively. All interactions were examined before using a process of backwards elimination where non-significant interactions were dropped from the analyses. The same traits were analysed against each of the covariates for both gender and genotype and, in most cases, only significant results are presented. Shear force values for *l. dorsi* and *semimembranosus* muscles were analysed by analysis of variance.

RESULTS

The range in HCW provided a sound basis for the development of regression equations and subsequent comparisons, with good overlap in both hybrid (range 65.6–83.5 kg) and red (range 78–85.4 kg) males and hybrid (range 54.6–83.0 kg) and red (range 60.4–72.6 kg) females.

Carcass component comparisons

Genotype and gender effects on muscle, bone, and fat components were analysed using HCW as a covariate. Hybrids had 25% and 26% less intramuscular fat in the *l. dorsi* and *semimembranosus*, respectively (Table 2). Males had 8% more total carcass muscle, 13% more total carcass bone, 46% less total carcass fat, and a 64% lower GR than females (Table 3). The *l. dorsi* muscle in males had 32% less intramuscular fat compared with females at the same HCW but this did not apply to the *semimembranosus* muscle.

Tissue distribution comparisons

Hybrids had smaller *supraspinatus* (5%) and *l. dorsi* (6%) and significantly larger *vastus* (6%), *rectus femoris* (6%), *semitendinosus* (9%), *gastrocnemius* (10%), and hind leg total muscle (5%) compared with reds (Table 4). There were no differences in bone or fat partitioning between the two genotypes when using total bone and total fat as covariates, respectively (data not presented).

Males had 10% less rib/loin other muscle, 9% less total rib/loin muscle, and 8% less hind leg *vastus* than females (Table 5). There was a significant HCW by gender interaction for rib/loin bone and, therefore, direct comparisons, except at the mean HCW, were inappropriate (Table 6). Males had 11% more shoulder bone compared with females (Table 7). Males had 12% more neck/shoulder fat weight than females (Table 8).

Shear force

The analysis of variance for shear forces yielded no significant genotype or gender effects for *semimembranosus*. *Semimembranosus* shear force trends were that hybrids were tougher than reds (4.79 versus 4.44 kg, SED 0.31) and males tougher than females (4.81 versus 4.42 kg SED 0.31). Similar analysis of *l. dorsi* shear force revealed no significant genotype effect (hybrid 2.87 versus red 2.60 kg SED 0.20) but there was a significant gender effect (M 2.98 versus F 2.50, $P < 0.01$).

DISCUSSION

Female pure Père David's deer have a 70% greater mature live weight than reds (Loudon et al. 1989). Heterosis could not be calculated in this experiment as pure PD were not run with the hybrid and red genotypes. Calculations of expected live weights assuming no heterosis (either positive or negative) and, accounting for the genetic divergence between the species (Tate et al. 1995) and the highly inbred nature of PD deer, place the PD around 52% heavier than reds. It has previously been shown that female

Table 2 Adjusted mean values (logarithmic and back-transformed values) at 72.9 kg hot carcass weight (HCW) and allometric regression parameters for carcass components, GR, EMA, and intramuscular fat content for hybrids and red deer. NS, not significantly different; *, $P < 0.05$; **, $P < 0.01$. % diff is percentage change from red genotype where genotypes differ significantly. GR is the tissue depth over the 12th rib, 16 cm from the midline. EMA is the cross-sectional area of *longissimus dorsi* and the *multifidus* muscle over the 12th rib.

	Genotype comparison				Regression parameters		
Component	Hybrid	Red	% diff	Average SEM	*b* slope (s.e.)	r^2	RSD
Total carcass weights							
muscle	4.668(46.56) NS	4.663(46.03)	–	0.0038	0.890(0.0657)	0.97	0.0122
bone	4.027(10.64) NS	4.023(10.54)	–	0.0095	0.792(0.1647)	0.84	0.0307
fat	3.921 (8.34) NS	3.931 (8.53)	–	0.0281	1.761 (0.4866)	0.61	0.0907
Other traits							
GR (mm)	1.166(14.7) NS	1.169(14.8)	–	0.0502	2.136(0.8668)	0.57	0.1616
EMA (cm^2)	1.581(38.1) NS	1.604(40.2)	–	0.0177	0.927(0.3063)	0.49	0.0571
Intramuscular fat %							
longissimus dorsi	0.371 (2.35) **	0.495 (3.13)	– 25	0.0301	1.212(0.5209)	0.54	0.0971
semimembranosus	0.234 (1.71) **	0.359 (2.29)	– 26	0.0181	–0.1045(0.3134)	0.63	0.0584

Table 3 Adjusted mean values (logarithmic and back-transformed values) at 72.9 kg hot carcass weight (HCW) and allometric regression parameters for carcass components, GR, EMA, and intramuscular fat content for male and female deer. NS, not significantly different; *, $P < 0.05$; **, $P < 0.01$. % diff is percentage change from female where genders differ significantly. GR is the tissue depth over the 12th rib, 16 cm from the midline. EMA is the cross-sectional area of *longissimus dorsi* and the *multifidus* muscle at the 12th rib.

	Gender comparison				Regression parameters		
Component	Male	Female	% diff	Average SEM	*b* slope (s.e.)	r^2	RSD
Total carcass weights							
muscle	4.722(52.72) **	4.687(48.64)	8	0.0043	0.890 (0.0657)	0.97	0.0122
bone	4.052(11.27) **	3.999 (9.98)	13	0.0108	0.792 (0.1647)	0.84	0.0307
fat	3.793 (6.21) **	4.059(11.46)	– 46	0.0319	1.761 (0.4866)	0.61	0.0907
Other traits							
GR (mm)	0.949 (8.9) **	1.387(24.4)	– 64	0.0568	2.136 (0.8668)	0.57	0.1616
EMA (cm2)	1.589(38.2) NS	1.596(39.4)	–	0.0177	0.927 (0.3063)	0.49	0.0571
Intramuscular fat %							
longissimus dorsi	0.349 (2.23) **	0.516 (3.28)	– 32	0.0352	1.212 (0.5209)	0.54	0.0971
semimembranosus	0.271 (1.87) NS	0.320 (2.09)	–	0.0212	–0.1045(0.3134)	0.63	0.0584

Table 4 Adjusted mean values (logarithmic and back-transformed values) at 51.2 kg total muscle weight (TM) and allometric regression parameters for carcass muscle of hybrids and red deer. NS, not significantly different; *, $P < 0.05$; **, $P < 0.01$. % diff is percentage change from red genotype where genotypes differ significantly.

	Genotype comparison				Regression parameters		
Muscle	Hybrid	Red	% diff	Average SEM	*b* slope (s.e.)	r^2	RSD
Neck muscle	3.756(5.70) NS	3.815(6.53)	–	0.0252	1.326(0.4645)	0.73	0.0814
Shoulder							
deltoideus	2.414(0.26) NS	2.416(0.26)	–	0.0065	0.961(0.1206)	0.92	0.0211
supraspinatus	3.007(1.02) *	3.030(1.07)	– 5	0.0061	0.837(0.1154)	0.91	0.0200
infraspinatus	3.073(1.18) NS	3.073(1.18)	–	0.0088	0.924(0.1618)	0.80	0.0283
biceps brachii	2.549(0.35) NS	2.540(0.35)	–	0.0091	0.732(0.1685)	0.79	0.0295
other	3.887(7.71) NS	3.881(7.60)	–	0.0114	0.839(0.2111)	0.71	0.0370
Total	4.023(10.54) NS	4.020(10.47)	–	0.0082	0.847(0.1505)	0.83	0.0264
Rib/loin							
longissimus dorsi	3.625(4.22) *	3.652(4.49)	– 6	0.0078	1.097(0.1517)	0.86	0.0253
other	3.937(8.65) NS	3.940(8.71)	–	0.0074	1.317(0.1379)	0.90	0.0239
Total	4.111(12.91) NS	4.119(13.15)	–	0.0058	1.250(0.1076)	0.93	0.0189
Hind leg							
gluteus	3.270(1.86) NS	3.250(1.78)	–	0.0144	0.858 0.2661)	0.56	0.0466
vastus	3.581(3.81) **	3.556(3.60)	6	0.0056	1.013(0.1032)	0.91	0.0181
rectus femoris	3.626(4.23) **	3.600(3.98)	6	0.0060	0.769(0.1047)	0.93	0.0182
semimembranosus	3.459(2.88) NS	3.471(2.96)	–	0.0079	0.697(0.1457)	0.84	0.0255
semitendinosus	3.106(1.28) **	3.067(1.17)	9	0.0085	0.830(0.1612)	0.85	0.0280
gastrocnemius	3.185(1.53) **	3.144(1.39)	10	0.0096	1.119(0.1799)	0.85	0.0315
other	3.760(5.75) NS	3.741(5.51)	–	0.0095	0.843(0.1733)	0.81	0.0301
Total	4.329(21.33) **	4.312(20.51)	5	0.0031	0.861(0.0573)	0.97	0.0099

Table 5 Adjusted mean values (logarithmic and back-transformed values) at 51.2 kg total muscle weight (TM) and allometric regression parameters for carcass muscle of male and female deer. NS, not significantly different; *, $P < 0.05$; **, $P < 0.01$. % diff is percentage change from female where genders differ significantly.

	Gender comparison				Regression parameters		
Muscle	Male	Female	% diff	Average SEM	*b* slope (s.e.)	r^2	RSD
Neck muscle	3.825 (6.68) NS	3.746 (5.58)	–	0.0340	1.326 (0.4645)	0.73	0.0814
Shoulder							
deltoideus	2.422 (0.26) NS	2.408 (0.26)	–	0.0088	0.961 (0.1206)	0.92	0.0211
supraspinatus	3.023 (1.05) NS	3.013 (1.03)	–	0.0085	0.837 (0.1154)	0.91	0.0200
infraspinatus	3.065 (1.16) NS	3.081 (1.21)	–	0.0118	0.924 (0.1618)	0.80	0.0283
biceps brachii	2.552 (0.36) NS	2.538 (0.35)	–	0.0123	0.732 (0.1685)	0.79	0.0295
other	3.884 (7.66) NS	3.884 (7.66)	–	0.0154	0.839 (0.2111)	0.71	0.0370
Total	4.021(10.50) NS	4.022(10.52)	–	0.0111	0.847 (0.1505)	0.83	0.0264
Rib/loin							
longissimus dorsi	3.624 (4.21) NS	3.654 (4.51)	–	0.0112	1.097 (0.1517)	0.86	0.0263
other	3.915 (8.22) *	3.962 (9.16)	– 10	0.0101	1.317 (0.1379)	0.90	0.0239
Total	4.095(12.45)**	4.135(13.65)	– 9	0.0079	1.250 (0.1076)	0.93	0.0189
Hind leg							
gluteus	3.250 (1.78) NS	3.270 (1.86)	–	0.0194	0.858 (0.2661)	0.56	0.0466
vastus	3.552 (3.56) *	3.586 (3.85)	– 8	0.0075	1.013 (0.1032)	0.91	0.0181
rectus femoris	3.623 (4.20) NS	3.603 (4.01)	–	0.0077	0.769 (0.1047)	0.93	0.0182
semimembranosus	3.475 (2.99) NS	3.455 (2.85)	–	0.0107	0.697 (0.1457)	0.84	0.0255
semitendinosus	3.093 (1.24) NS	3.079 (1.20)	–	0.0118	0.830 (0.1612)	0.85	0.0280
gastrocnemius	3.157 (1.44) NS	3.173 (1.49)	–	0.0132	1.119 (0.1799)	0.85	0.0315
other	3.753 (5.66) NS	3.748 (5.60)	–	0.0127	0.843 (0.1741)	0.81	0.0301
Total	4.320(20.89) NS	4.320(20.89)	–	0.0042	0.861 (0.0573)	0.97	0.0099

1/4 Père David's / 3/4 red hybrids had live weights 8% heavier than reds (Goosen 1997). On this basis, the expected live weight of the pure PDs would be $4 \times 8\% = 32\%$. In fact, the difference between these genotypes reported by Loudon et al. (1989) was 70%. Even with some allowance for a genotype by environment interaction, this suggests that the backcross hybrids in the current study (reared indoors) performed well below expectation as males and females achieved live weights 2.6% and 1.9% lower than red deer, respectively.

The allometric function allows for comparisons of tissues and organs independent of time. It provides an analysis independent of fixed time or degree-of-maturity constraints by fitting a regression line to data over a range in maturities to test if the trend is different from that observed in another group. Thus, using the allometric function, the observed differences are not maturity effects and are true genotype or gender effects.

Broad comparisons of allometric growth coefficients (b), which reflect the rate of growth of tissues relative to HCW (covariate), across genotype and gender groups revealed the same patterns as observed in cattle and in most mammals (Berg & Butterfield 1976), that bone matured earlier than muscle which matured earlier than fat. This early maturing nature of bone allows it to be used as an indicator or predictor of mature size at a relatively early stage of growth.

Table 6 Logarithmic adjusted least square means for the trait which had a covariate by fixed effect interaction and regression parameters for the allometric function $y = ax^b$. *, $P < 0.05$; **, $P < 0.01$.

					Regression parameters		
Component	Interaction	Main effect	Least squares mean	Average SEM	b slope (s.e.)	r^2	RSD
Rib/loin bone	TB*gender	Male	3.436 (2.73)*		1.784* (0.2130)		
		Female	3.508 (3.22)	0.0145	1.124 (0.3094)	0.90	0.0294

Table 7 Adjusted mean values (logarithmic and back-transformed values) at 10.8 kg total bone weight (TB) and allometric regression parameters for carcass bone for male and female deer. NS, not significantly different; *, $P < 0.05$; **, $P < 0.01$. Valid comparisons cannot be made for this trait (except at the mean HCW) because there was a HCW by gender interaction. For gender b coefficients see Table 6. % diff is percentage change from female where genders differ significantly.

	Gender comparison				Regression parameters		
Bone	Male	Female	% diff	Average SEM	b slope (s.e.)	r^2	RSD
Neck	3.379 (2.39) NS	3.346 (2.22)	–	0.0248	0.870 (0.3051)	0.66	0.0594
Shoulder	3.420 (2.63) **	3.377 (2.38)	11	0.0068	0.777 (0.0853)	0.96	0.0166
Rib/loin	3.436 (2.73) *	3.509 (3.23)	– 15	0.0145	1.473 (0.1664)	0.87	0.0324
Hind leg	3.638 (4.35) NS	3.631 (4.28)	–	0.0065	0.915 (0.0796)	0.96	0.0155

Table 8 Adjusted mean values (logarithmic and back-transformed values) at 8.7 kg total fat weight (TF) and allometric regression parameters for carcass fat for male and female deer. NS, not significantly different; *, $P < 0.05$; **, $P < 0.01$. % diff is percentage change from female where genders differ significantly.

	Gender comparison				Regression parameters		
Fat	Male	Female	% diff	Average SEM	b slope (s.e.)	r^2	RSD
Neck/shoulder	3.366 (2.32) *	3.315 (2.07)	12	0.0153	0.918 (0.0843)	0.89	0.0419
Rib/loin	3.592 (3.91) NS	3.627 (4.24)	–	0.0134	1.211 (0.0798)	0.96	0.0397
Hind leg	3.429 (2.69) NS	3.389 (2.45)	–	0.0191	0.729 (0.1129)	0.74	0.0562

Component comparisons

Genotype effects at the same HCW were pronounced, with hybrids having significantly less intramuscular fat in both *l. dorsi* and *semimembranosus*. Hybrids also tended to have greater bone masses than reds but the same rate of growth of bone tissue. Hybrids may reach greater mature size than reds based on the mature weights of the two parental breeds (Whitehead 1993) and the opportunity for heterosis in these hybrids (Falconer 1982). The fact that no heterosis was observed in the hybrids may simply be a reflection of better adaptation to the indoor environment by the red deer.

The gender effects observed were as expected, with males having more total carcass muscle and bone and less fat than females at the same HCW. Similar gender effects have been observed in sheep (Thompson et al. 1985; Butler-Hogg & Brown 1986) and cattle (Fortin et al. 1981). Comparisons with other studies in deer are difficult because of differences in nutrition, live weight, and dissection techniques. Males and females at 15 and 14 months of age raised on pasture had carcass fat percentages of 8.4% and 10.5%, respectively (Wenham & Pennie 1986), which compare favourably with those of 10% and 15% in this study considering the differences in nutrition and age. Studies of older animals on pasture also indicate higher carcass fat percentages in females (Mitchell et al. 1976).

Tissue distribution comparisons

Genotype effects on tissue distribution reveal a tendency for a relatively smaller proportion of muscle in the shoulder but more in the hind leg primal of hybrids compared with red deer. This is similar to other comparisons between Père David's, $^1/_4$ Père David's / $^3/_4$ red deer hybrids, and reds (Goosen 1997). In cattle breeds and several other mammals it has been shown that muscle distribution is relatively constant within gender and slaughter weight groups (Berg & Butterfield 1976). More recently, studies on major genes have highlighted exceptions to this as is demonstrated in cattle by the myostatin gene and its effect on muscle hyperplasia (Grobet et al. 1997, 1998) and enhanced muscle development associated with muscle fibre hypertrophy in callipyge sheep (Cockett et al. 1994) and Piétrain pigs (Fujii et al. 1991). In this study, we have illustrated a significant difference in muscle distribution between two deer genotypes that may be more genetically diverse or distinct than cattle breeds. While this may be a major gene effect we currently have no molecular data which provide evidence to support this.

In the present study the influence of gender on tissue distribution indicated a greater proportion of the total carcass muscle in the rib/loin primal of females. This is similar to studies in sheep where females had a greater proportion of total carcass muscle in the rib/loin area than males (Taylor et al. 1989). The comparative distribution of bone and fat in male and female deer reflects the relatively greater proportion of the carcass in the caudal regions. This effect of gender appears consistent with the evolutionary pressures on red deer males to large body size and the importance of "advertisement" in the context of reproductive success (Clutton-Brock & Albon 1979; Clutton-Brock et al. 1982). In addition, this advertisement is more than appearances, as neck and leg strength play a role in inter-male contests. Although sheep have been domesticated for much longer than deer (still considered as semi-domesticated in New Zealand), rams also deposit a greater proportion of their total fat in the shoulder region and less in the rib/loin regions than ewes (Butler-Hogg & Brown 1986; Taylor et al. 1989). In this study the rib/loin bone allometric growth coefficient (b) in males indicated that bone growth in this primal cut was later maturing than in females (M 1.779 versus F 1.128).

There was no significant gender by genotype interaction for neck muscle but the trend was for males to have more muscle than females. This also concurs with the shift in muscle distribution observed in comparisons between castrate and entire deer where castrate forequarter muscle was proportionately 7% lighter and hindquarter muscle was proportionately 7% heavier than in entire males (Tan & Fennessy 1981). Rams have also been shown to have higher proportions of their muscle in the neck and shoulder compared with ewes (Taylor et al. 1989).

Comparative production efficiency is likely to determine whether the hybrid system is adopted in practice. If the genetic control of muscle distribution could be separated using QTL detection techniques such as has been done in deer (Goosen 1997), then deriving programs for the introgression of these gene regions into red deer may be useful.

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