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CARCASS COMPOSITION IN MALE FALLOW DEER: AGE AND CASTRATION EFFECTS ON DISSECTED TISSUE DISTRIBUTION

B. W. Hogg, L. M. Catcheside, G. J. K. Mercer
Ministry of Agriculture and Fisheries, Ruakura Agricultural Centre, Hamilton, New Zealand

ABSTRACT

Twenty-eight male fallow deer (*Dama dama*), 14 entire and 14 castrated (seven each 1- and 2-year-old) were slaughtered and their carcasses jointed. Each joint was separated into venison, trim A (low visible fat, diced pieces), trim B (pieces suitable only for mincing), waste and bone. Castration had a significant and cumulative effect on live and carcass weights. At 1 year of age castrated males were 80 g/kg lighter in live weight; at 2 years this difference had increased to 119 g/kg. The pattern for differences in hot and cold carcass weights was similar, being 66 and 148 g/kg lighter at 1 and 2 years old, respectively.

Castration caused small but significant shifts in the proportions of the primal joints, and the proportions of venison, trim A and trim B. Castrated males had smaller neck (9 g/kg) and saddle (10 g/kg) joints, but 18 g/kg larger legs. In the whole carcass they contained 12 g/kg more venison, but correspondingly less trim A and trim B.

Older animals had higher proportions of venison and lower proportions of bone. Venison distribution altered with age, but this was mainly a reflexion of changes in joint proportions.

The overall effect of castration was to reduce carcass weights (on which producers are paid) and reduce venison production proportionately to 0·97 and 0·88 of that achieved in 1- and 2-year-old entire males respectively. In some market situations castration may be an acceptable method of producing venison outside of the normal peak production, but the reduced production would require higher schedule prices to be economically viable for the producer.

KEYWORDS: carcass composition, castration, fallow deer, growth.

INTRODUCTION

In New Zealand (NZ) the fallow deer (*Dama dama*) population constitutes proportionately 0·1 of the total farmed deer population, with 30 000 breeding females. As an expanding industry its venison production is based upon the slaughter of excess male animals and culled females. These males are usually left entire and do not normally pose major handling problems at these young ages. However, Mulley and English (1985) suggested that castration of young males destined for slaughter during the breeding season may ease handling and bruising problems which can occur. The castrated males were lighter in carcass weight and had a reduced dressing proportion, leading to considerably lower returns. They concluded that there would have to be considerable financial incentive to contemplate castration. Asher (1985) noted some changes in fat trim required with age, which caused decreases in trimmed saleable meat yield with age. However, limited data are currently available on the composition or distribution of the commercial components of male fallow deer carcasses (e.g. Gregson and Purchas, 1985). The present work aimed to describe the effects of age and castration on venison production and other components of saleable product in fallow deer at commercial carcass weights at either 1 or 2 years of age.

MATERIAL AND METHODS

All 28 deer were grown at the Ruakura Agricultural Centre on the Deer Unit. Castration was by elastrator rubber rings at 5 months of age. The entire and castrated animals were run as one group, with half being slaughtered in January at 1 year and the remaining 14 carried on until 2 years of age. Animals were weighed at monthly intervals. They were transported in a specially constructed deer transporter to Game Meats (NZ) Ltd Deer Slaughter Plant, a distance of 200 km, and held overnight in darkened pens.

They were slaughtered the following morning by stunning with a captive bolt pistol, then severing both carotid arteries and jugular veins. They were dressed following normal commercial practice, weighed hot, and placed in a chiller where they were held overnight. On the day following slaughter the carcasses were reweighed and split down the mid line. The half carcass was broken into a shoulder, flap, neck, saddle and leg joint (Figure 1). Each joint was then boned out and the component parts — venison, shin, trim A, trim B, waste and bone, depending upon the joint, were weighed. In its broadest sense venison is considered by processors and marketers to be the saddle and the leg, the high value parts of the carcass. In this work venison is defined as the boned-out and trimmed muscles of the saddle, leg and shoulder (although the saddle is usually sold as a bone-in joint). The remaining muscle is sold as trim and shin. Depending upon market requirements the leg may be sold bone-in, or boned-out, in which case it yields venison (the larger muscles), shin, trim A and trim B. The shoulder when boned out can produce high value venison cut described as shepherd's steak.

Trim A is muscle plus fat from the various joints which are low in visible fat and able to be diced. Trim B is muscle in pieces which are high in visual fat and more suited to mincing. Shin is muscle and any associated fat. Each component was cryovac packed and frozen prior to mincing for proximal chemical analyses. That work will be reported subsequently.

Data were analysed by two-way analysis of variance, with age and castration as main effects.

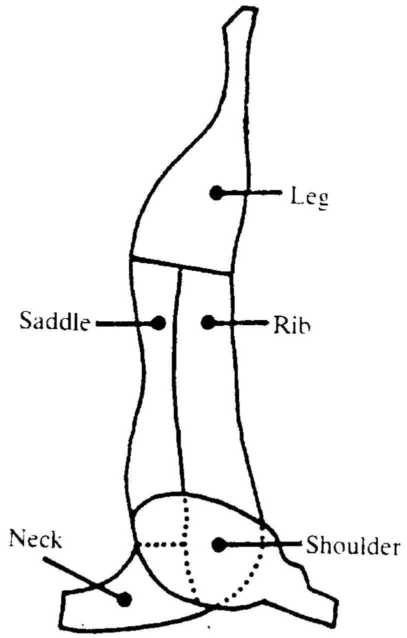

FIG. 1. The primal joints of a fallow deer carcass.

RESULTS

As shown in Figure 2 and Table 1 the castrated males were lighter at both ages. Castration appeared to have a cumulative effect upon weight gain, with major differences occurring in the spring/summer growth period. As yearlings they were 3·5 kg (80 g/kg) lighter than the entires. This difference in favour of the entires had increased to 6·5 kg (119 g/kg) in the 2-year-old animals. The same pattern of difference between entire and castrated males at 1 and 2 years was evident for both hot and cold carcass weight.

There was an interaction between castration and age for dressing-out proportion, with dressing-out proportion increasing with castration in the yearlings, but decreasing with castration for the 2-year-olds.

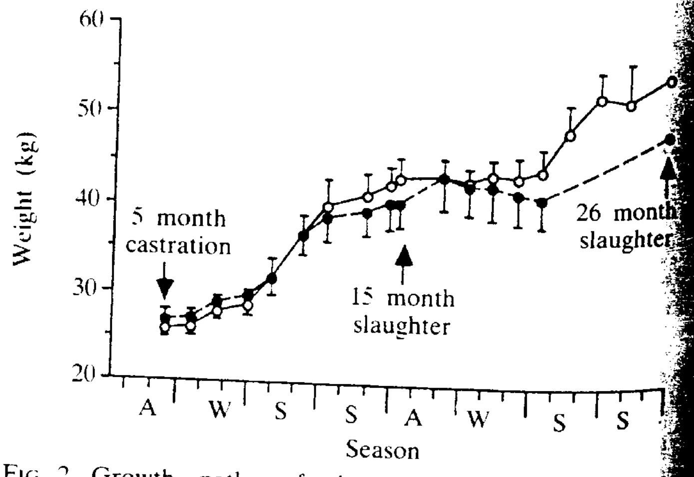

FIG. 2. Growth paths of the entire (○——○) and castrated (●— — —●) male fallow deer.

TABLE 1

Live weights, carcass weights and primal joint proportions in 1- and 2-year-old entire and castrated male fallow deer

	Age				Significance of difference			
	1 year		2 years					
	Entire	Castrated	Entire	Castrated			Sex	
No.	7	7	7	7	Sex	Age	× age	s.e.d.
Live weight (kg)	44·0	40·5	54·8	48·3	***	***		1·57
Hot carcass weight (kg)	24·5	22·9	30·6	26·2	***	***	*	0·92
Cold carcass weight (kg)	24·2	22·6	29·8	25·4	***	***	*	0·90
Dressing-out proportion	0·55	0·56	0·55	0·54		*	*	0·0068
Shoulder (g/kg)	177	181	170	176				4·9
Rib (g/kg)	139	139	116	120		***		3·1
Neck (g/kg)	113	103	125	117	*	**		5·3
Saddle (g/kg)	176	169	174	162	***			3·6
Leg (g/kg)	395	413	405	423	***	**		4·8

Castration caused a shift in primal joint proportion (Table 1) with castrated males having 9 g/kg less neck and 10 g/kg less saddle, but 18 g/kg more in the leg joint. There were no interactions between age and castration. As animals increased in age there was also a change in joint proportions but again, like the effects of castration, this was quite small in magnitude. The 2-year-old animals had 13 g/kg more of the carcass in the neck and 10 g/kg more in the leg, while the rib joint was 21 g/kg less. Over both age and sex groups the mean distribution of carcass weight as primal joints was (g/kg): shoulder, 176; rib, 129; neck, 114; saddle, 170; and leg, 409. Thus, the high value joints, saddle and leg, constitute 579 g/kg of the total carcass weight.

Castration also had an effect on the proportions of the commercial carcass components (Table 2). Castrated males contained 11 g/kg more venison, but less trim A (13 g/kg) and less trim B (6 g/kg). The other differences were not significant, while there was a significant sex by age interaction for trim A, with the decline in trim A proportions in the 2-year-old castrated males being greater than that in the yearlings.

Two-year-olds had significantly more bone (21 g/kg) and 26 g/kg more trim A than yearling animals, but there were no other significant differences due to age. While bone

TABLE 2

Commercial carcass composition (g tissue per kg carcass weight) of 1- and 2-year-old entire and castrated male fallow deer

	Age				Significance of difference			
	1 year		2 years					
							Sex	
Component	Entire	Castrated	Entire	Castrated	Sex	Age	× age	s.e.d.
Venison	350	364	353	363	**			4·6
Trim A†	145	140	179	157	**	***	*	5·5
Trim B‡	168	166	124	114	***			13·8
Shin	93	94	88	93				2·4
Waste	12	11	15	10				3·7
Bone	235	224	242	261		***	**	6·0

† Pieces of meat low in visible fat and able to be diced.
‡ Pieces of meat high in visible fat, only suitable for mincing.

TABLE 3
Distribution of commercial components between the five primal joints (as g/kg total weight of that component) in 1- and 2-year-old entire and castrated male fallow deer

		Age				Significance of difference			
		1 year		2 years					
Component	Joint	Entire	Castrated	Entire	Castrated	Sex	Age	Sex × age	s.e.d.
Venison	Shoulder	136	131	142	134	**	*		2·8
	Saddle	264	252	246	229	**	***		7·0
	Leg	600	616	612	637	***	***		5·8
Trim A	Shoulder	158	165	128	158				14·5
	Rib	135	132	140	158		*		9·7
	Neck	458	433	406	337	***	***		18·4
	Saddle	110	124	132	141				15·1
	Leg	140	146	186	207		***		10·0
Trim B	Shoulder	171	180	222	217		**		20·8
	Rib	471	479	568	542		*		25·4
	Leg	358	341	302	241	*	***		22·2
Shin	Shoulder	530	522	498	511		**		10·0
	Leg	470	478	502	489		**		10·0
Bone	Shoulder	136	138	123	115		**	**	8·7
	Rib	173	177	130	131		***		8·9
	Neck	180	171	211	210		***		10·0
	Saddle	269	237	230	198	**	**		15·5
	Leg	254	278	313	333	**	***		10·1

content increased with age, the increase was much greater in the castrates compared with the entires (36·7 and 6·6 g/kg respectively) giving a significant interaction between age and sex. Over all animals the mean carcass composition was (g/kg): venison, 358; trim A, 155; trim B, 143; shin, 92; waste, 12; and bone, 241. Thus, 748 g/kg of the carcass is saleable product, but only 358 g/kg of the boned-out weight is high-value product.

The distribution of individual commercial components (venison, trim A, etc.) was affected by both castration and age, although, like the changes in joint proportions or tissue proportions, the differences observed between groups was small, and rarely greater than 20 g/kg.

Castration influenced venison distribution between the three joints producing this product but had little effect on the other components of the carcass except for bone weight (Table 3). In contrast to this, age influenced the distribution of all components to some degree. The leg joint is the major contributor to total venison, but the shoulder is quite valuable for its shepherd's steak. Over all groups, venison distribution was (g/kg): leg, 616; saddle, 248; and shoulder, 136. The castrated males had 6 g/kg less of their total venison in the shoulder and 14 g/kg less in the saddle, but 21 g/kg more in the leg. Two-year-olds contained 4 g/kg more venison in the shoulder and 16 g/kg more in the leg, but 20 g/kg less in the saddle.

Over all groups trim A was distributed as follows (g/kg): shoulder, 152; rib, 141; neck, 408; saddle, 127; and leg 170. The neck had the highest proportional content of boneless meat which is almost devoid of fat and so meets the specifications of trim A.

Trim B, which was higher in fat content than trim A, is derived from the shoulder, rib and leg joints with 500 g/kg coming from the rib, followed by 311 g/kg in the leg and 197 g/kg in the shoulder. Although the proportional changes with changing age are quite large (e.g. 50 g/kg for the rib joint), the low total proportion of trim B in the carcass means these shifts in distribution do not have a major economic effect on individual joint value.

Castration had a relatively minor influence

TABLE 4
The proportions of each commercial component (as g/kg joint weight) in each of the primal joints in 1- and 2-year-old entire and castrated male fallow deer

		Age				Significance of difference			
		1 year		2 years					
Joint	Component	Entire	Castrated	Entire	Castrated	Sex	Age	Sex × age	s.e.d.
Shoulder	Venison	271	264	291	277		**		6·3
	Trim A	129	127	140	142				13·9
	Trim B	163	166	159	140				19·6
	Shin	274	273	252	270				8·9
	Bone	182	170	170	171				10·2
Rib	Trim A	141	135	216	207		***		14·4
	Trim B	567	572	521	510		**		22·5
	Bone	292	287	262	284				14·4
Neck	Trim A	587	589	572	456	**	***	***	23·4
	Waste	38	37	34	46				11·0
	Bone	375	374	394	498	**	***	**	20·9
Saddle	Venison	524	561	536	515		*		41·1
	Trim A	90	106	90	136		*		41·6
	Waste	26	12	53	35	*	**		11·2
	Bone	360	322	321	319				22·2
Leg	Venison	532	543	525	546	**			7·4
	Trim A	51	50	80	77		***		4·8
	Trim B	151	136	94	65	***	**		7·8
	Shin	113	109	110	107		.		2·5
	Waste	9	12	2	0		*		4·9
	Bone	150	151	189	205	*	***	*	5·2

on total bone distribution (Table 3), with castrated males having 33 g/kg less bone in the saddle, but 22 g/kg more bone in the leg joint, compared with entire males. In contrast, age had quite large effects on bone distribution, with the 2-year-old animals having 57 g/kg more of their bone in the hind limb, and 35 g/kg more in the neck joint. Conversely, there was 18 g/kg less in the shoulder, 44 g/kg less in the rib and 38 g/kg less in the saddle of the 2-year-old animals. These differences in distribution reflect variation in maturity of differing bones and bone groups and the developmental changes that occurred between 1 and 2 years of age. The proportions (g/kg) of total bone in each joint for 1- and 2-year-olds respectively were as follows: shoulder, 137, 119; rib, 175, 131; neck, 176, 211; saddle, 253, 214; and leg, 266, 323.

Castration had minor effects on the composition of individual joints, with only the leg joint being significantly affected in venison content (Table 4). Entire males had on average 15 g/kg lower venison content compared with castrated males: 529 and 544 g/kg respectively. Both the saddle and leg which between them contained proportionately 0·86 of the total venison in the carcass yielded only 515 to 562 g/kg of their joint weight as high-priced venison. However, the saddle in particular is usually sold bone-in, so the total joint weight is considered high value. In contrast, depending upon the market, the leg may be boned out.

Increasing age had significant effects on the proportions of saleable components in all five

TABLE 5
Mean composition of each of the five primal joints (g/kg)

	Joint				
Component	Shoulder	Rib	Neck	Saddle	Leg
Venison	276			522	537
Trim A	135	174	551	117	64
Trim B	157	543			112
Shin	269				110
Waste		2	39	31	6
Bone	172	281	410	330	174

joints (Table 4). Because composition of a joint has been expressed as a proportion of the weight of that joint, shifts in composition were greater than that observed for the whole carcass, with differences between 1- and 2-year-olds ranging from 16 g/kg for shoulder venison, to 74 g/kg for neck trim A and neck bone.

For descriptive purposes the mean composition of each joint is given in Table 5. While the proportion (g/kg) of high-value venison in a joint ranged from 530 for the leg and saddle, down to 276 for the shoulder, the proportion of bone ranged from 410 in the neck, to a low of 170 in the shoulder and leg.

DISCUSSION

Effects of castration

Castration had a major effect on growth rate and hence live and carcass weights (see Figure 2). The reduced growth rates of the castrated males in this study agree with results of Adam (1988) with fallow deer in NZ, Mulley and English (1985) with fallow deer in Australia, and Drew, Fennessy and Greer (1978) with red deer reared in NZ. The effect of castration was to reduce growth rate, particularly in the spring/summer period when males are undergoing major changes in differential muscle growth and fatness in preparation for the rut (Drew, 1985; Field, Young, Asher and Foote, 1985).

In NZ, castrated animals of 15 months were around 80 g/kg lighter than entire animals. Mulley and English (1985) observed a difference of 137 g/kg in their Australian study. Their bigger difference arose because of the heavier weights achieved by the entire males (48·3 kg), compared with 44·0 kg in the present study. Weights of the castrated animals were similar in both studies: 40·5 in this work and 41·7 kg in theirs.

The effect of castration on weight, both live and carcass, was cumulative, so that the differences in carcass weights between castrated and entire males increased from 1 to 2 years of age. As 2-year-old animals the carcasses of the castrated males were 148 g/kg lighter (4·40 kg) compared with a 66 g/kg difference (1·60 kg) at 1 year of age. The bigger difference between entire and castrated males at 2 years, compared with yearling, is a reflexion of the greater growth response to changing testosterone levels in the 2-year-old males. Asher, Peterson and Bass (1989) have shown clearly the major difference in testosterone secretion patterns of entire and castrated males, and the relative differences between 1- and 2-year-old animals, as well as their associated growth patterns (Asher, Day and Barrell, 1987).

The smaller neck joint proportion in the castrated animals was also indicative of the direct effect testosterone has on differential muscle growth going into the rut. The normal hypertrophy of the neck muscles and associated changes in muscle distribution which occurs for deer going into the rut was absent in the castrated males, supporting the contention of Field *et al.* (1985) that testosterone has a direct effect on specific muscles at this time. McCall (1985) showed that the *m. splenius* amd *m. semspinalis* of fallow deer had increased growth rates in the immediate pre-rut period. Tan and Fennessy (1981) demonstrated the effect of castration on individual muscles in red deer, with the greatest changes (between castrated and entire males) being for the *m. splenius* in the neck region, but also reductions in relative growth of some of the major muscles in the hind limb. Thus, the differences in joint weight distribution were not only an effect of castration, and the inability of the castrated males to show the normal seasonal muscle growth response, but also to changes in fatness. Drew *et al.* (1978) showed that castrated red deer had proportionately 0·1 more fat than entire red deer. Although a major part of this fat is as intermuscular fat (Gregson and Purchas, 1985), there were also increases in subcutaneous fat, and this may have had some influence additionally on the leg, and to a lesser extent, the saddle proportions.

Because this study used commercial cutting and boning it is not possible to describe the carcass in terms of muscles and fat deposits. However, it seems likely based on other data (e.g. Drew *et al.*, 1978) that the castrated animals contained more fat. However, unless the saddle joint, which contains a large part of the subcutaneous fat as a distinct pad (Gregson and Purchas, 1985), is extremely fat, it is not trimmed, as this detracts from its visual appearance and commercial acceptability. For this reason, any differences in fatness between the castrated and entire males would not show in the data. Thus changes in joint proportions are a combination of differential growth of muscle and fat with the two effects sometimes working in opposite directions.

The major determinant of value to the producer is carcass weight, and to the processor, weight of high-value product (there being up to a 20-fold difference in price between venison and other products). For the producer, castration imposes a cost: firstly, by reducing carcass weight and, secondly, if the carcass fails to reach 24 kg, by being paid a lower price per kg. Thus, the castrated males in this study would have returned the producer $122, compared with $135 for the entire males at 1 year; proportionately about 0·1 less. At 2 years of age the proportional difference had increased to 0·16 or $28. At the same time, the return to the processor is also less from the castrated males, primarily because of reduced weight; the small shifts in composition having an insignificant effect upon total return. It would appear that unless there were severe handling problems, which result in excessive bruising and loss of product to the processor, castration is neither necessary nor economically feasible. If unforseen behavioural problems did necessitate castration for animals specifically intended for slaughter around the time of the rut, there would have to be a large price differential paid for castrated animals. In the present NZ payment system that is unlikely to occur.

Effects of age

Both the dominant species of deer farmed in NZ exhibit highly seasonal patterns of growth and compositional changes associated with reproductive activity (Drew, 1985; Wallace and Davies, 1985; Asher *et al.*, 1987). In addition, growing deer show the normal pattern of growth and development associated with increasing weight and age (Gregson and Purchas, 1985). McCall (1985) has shown that dissected fat is late maturing, muscle intermediate, maturing at nearly the same rate as the carcass, while bone is early maturing. At the level of the commercial cuts, Gregson and Purchas (1985) reported that the hind limb joint and neck were early maturing, while the rib was late maturing, implying a centripetal growth pattern culminating in the ventral body region. This contrasts with the present study which indicated that the leg became a slightly bigger proportion of the carcass with increasing age and weight. The differences observed could be partly a reflexion of the variability associated with commercial cutting and the low numbers of observations. There may have been also an effect of increased fatness in the deer used by Gregson and Purchas (1985) because the 2-year-olds in their study were considerably heavier, having grown faster. The increase in fat tends to be concentrated in the rib region, particularly for intermuscular fat, and this may have depressed the proportion of hind limb. It is unlikely that there were significant differences in muscle distribution. Dissection studies of muscle distribution in sheep (Butterfield, Zamora, James, Thompson and Williams, 1983; Butler-Hogg and Whelehan, 1987), sheep and goats (Thonney, Taylor, Murray and McClelland, 1987) and cattle (Butterfield and Berg, 1966) all indicate that muscle distribution is relatively fixed soon after birth. Changes in distribution were small (less than 20 g/kg total muscle) and at the level of commercial cutting economically unimportant. Wenham and Pennie (1986), in a study of muscle and bone growth in red deer, observed that the relative growth coefficient of the *m. splenius*, whilst having on average a value of 0·97, had nevertheless an increasing value with increasing total muscle weight. This may have been a reflexion of their data set, as animals were dissected at 15 and 26 months of age, when muscle hypertrophy was occurring, but there were no post-rut animals. In a study of commercial joint weights in 578 fallow deer slaughtered over the whole year and spanning the ages of 12 to 27 months, Butler-Hogg (1988) found that the leg joint was, on average, 425 g/kg of the carcass weight. This is slightly higher than the values found in this study, which in turn were about 10 g/kg higher than those of Gregson and Purchas (1985). Also, in an earlier study (Butler-Hogg, 1988) it was observed that older, heavier fallow deer tended to have slightly more of their carcass weight in the neck and shoulder. However, given the major effect on return to processor of the hind limb and saddle, this small shift in the older animals was insignificant in influencing the value of the carcass to the processor. The leg and saddle combined dominated the return to the processor, generating proportionately about 0·85 of total revenue. Their combined proportion changes little over the 2 years, reflecting the general stability of muscle distribution (outside the seasonal effect) and change associated with variation in fatness. In yearling males, the leg and saddle were 571 g/kg of carcass weight while at 2 years this value was 579.

The major incentive for fallow deer producers is to achieve carcass weights of better than 24 kg in yearling animals. In favourable years this may be possible, but growth rates can be variable with the result that carcass weights of yearlings may vary from 19 to 25 kg, and 2-year-olds from 28 to 36 kg (Gregson and Purchas, 1985; Butler-Hogg, 1988). Whilst as expected compositional changes do occur with changing age, these changes have little impact on the commercial value of a carcass because of its inherently low fat content and the way in which it is processed. The major influence is carcass weight, and the proportion of that weight in the leg and saddle. The major reason for a producer to take his stock on for a 2nd year, or even part of that year, is the possibility of not achieving the necessary 24 kg carcass weight. The additional 6 kg carcass weight of the 2-year-olds in this study is unlikely to be economic, given the added maintenance costs of the 2nd year feeding, and the opportunity cost of the capital tied up in that stock. A simple margins analysis suggests that a yearling operation will be more profitable, although changes in the schedule to encourage out of season production can have a big effect on potential profit. The aim of fallow producers must be to grow their stock well enough in their 1st year to achieve the 24 kg target weight.

Seasonal effects on composition

This study focussed on the composition of animals pre-rut, when they were growing quickly. However, there is an effect of season on the composition of deer, with the greatest changes in composition occurring between the pre- and post-rut periods. As animals approach the rut they lay down fat, which is then extensively mobilized during the rutting period (Drew, 1985; Wallace and Davies, 1985). During this time, mature stags may lose proportionately 0·25 of their live weight, with this loss in weight being almost entirely fat. In younger animals these weight changes are not so great (see Figure 2) but, in a study which encompassed all four seasons of the year Butler-Hogg, Catcheside, Mercer and Duganzich (1990) showed that joint weight distribution was changed. Again, the major difference occurred between pre- and post-rut animals (i.e. 15 months and 18 months old). While carcass weights of 139 animals were not different at these two times (24·0 kg) the proportion of the high-value cuts declined from 0·572 to 0·562 of the carcass. This occurred through a decline of 23 g/kg in the proportion of the saddle, in the post-rut animals, associated with a reduction in subcutaneous fat. The leg joint increased slightly as a proportion of the carcass, possibly due to tissue water changes (McCall, 1985). Over the same period omental fat weights of animals declined from 230 g pre-rut to below 100 g by mid winter (Butler-Hogg *et al.*, 1990).

Given the greater growth response to testosterone in the 2nd year it is likely that there will be bigger compositional changes occurring, both pre- and post-rut, compared with the yearlings. However, in most cases, particularly post-rut, these changes are unlikely to have a negative effect on carcass value, as carcass weight is the major determinant of value except in overfat animals.

As fatness levels are highest immediately pre-rut the results of this study and those of Butler-Hogg *et al.* (1990) suggest that it is unlikely that animals will be downgraded for overfatness at other times of the year.

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REFERENCES

ADAM, J. L. 1988. Growth. In *Progressive Fallow Farming* (ed. P. L. Allen and G. W. Asher), pp. 47-55. Ministry of Agriculture and Fisheries, Hamilton, NZ.

ASHER, G. W. 1985. Meat production from fallow deer. In *Biology of Deer Production* (ed. P. F. Fennessy and K. R. Drew). *Royal Society of New Zealand Bulletin 22*, pp. 299-301.

ASHER, G. W., DAY, A. M. and BARRELL, G. K. 1987. Annual cycle of liveweight and reproductive changes of farmed male fallow deer (*Dama dama*) and the effect of daily oral administration of melatonin in summer on the attainment of seasonal fertility. *Journal of Reproduction and Fertility* **79:** 353-362.

ASHER, G. W., PETERSON, A. J. and BASS, J. J. 1989. Seasonal pattern of LH and testosterone secretion in adult male fallow deer *Dama dama*. *Journal of Reproduction and Fertility* **85:** 657-665.

BUTLER-HOGG, B. W. 1988. Venison production. In *Progressive Fallow Farming* (ed. D. L. Allen and G. W. Asher), pp. 79-88. Ministry of Agriculture and Fisheries, Hamilton, NZ.

BUTLER-HOGG, B. W., CATCHESIDE, L. M., MERCER, G. J. K. and DUGANZICH, D. M. 1990. Venison production from fallow deer. In *Fallow Deer Farming — A Technical Guide* (ed G. Marshall and E. Hazelhurst). New Zealand Fallow Deer Society, Wellington. In press.

BUTLER-HOGG, B. W. and WHELEHAN, O. P. 1987. Muscle growth and distribution of muscle weight in Clun and Southdown sheep. *Animal Production* **44:** 133-142.

BUTTERFIELD, R. M. and BERG, R. T. 1966. A classification of bovine muscles based on their relative growth patterns. *Research in Veterinary Science* **7:** 326-332.

BUTTERFIELD, R. M., ZAMORA, J., JAMES, A. M., THOMPSON, J. M. and WILLIAMS, J. 1983. Changes in body composition relative to weight and maturity in large and small strains of Australian Merino rams. 2. Individual muscles and muscle groups. *Animal Production* **36:** 165-174.

DREW, K. R. 1985. Meat production from farmed deer. In *Biology of Deer Production* (ed. P. F. Fennessy and K. R. Drew). *Royal Society of New Zealand, Bulletin 22*, pp. 285-290.

DREW, K. R., FENNESSY, P. F. and GREER, G. J. 1978. The growth and carcass characteristics of entire and castrate red stags. *Proceedings of the New Zealand Society of Animal Production* **38:** 142-144.

FIELD, R. A., YOUNG, O. A., ASHER, G. W. and FOOTE, D. M. 1985. Characteristics of male fallow deer muscle at a time of sex-related muscle growth. *Growth* **49:** 190-201.

GREGSON, J. E. and PURCHAS, R. W. 1985. The carcass composition of male fallow deer. In *Biology of Deer Production* (ed. P. F. Fennessy and K. R. Drew), *Royal Society of New Zealand, Bulletin 22*, pp. 295-298.

MCCALL, J. E. 1985. The carcass composition and meat quality of male fallow deer. *M. Agric. Sci. Thesis, Massey, University, NZ.*

MULLEY, R. C. and ENGLISH, A. W. 1985. The effects of castration of fallow deer (*Dama dama*) on body growth and venison production. *Animal Production* **41:** 359-361.

TAN, G. Y. and FENNESSY, P. F. 1981. The effect of castration on some muscles of red deer (*Cervus elaphus* L.). *New Zealand Journal of Agricultural Research* **24:** 1-3.

THONNEY, M. L., TAYLOR, ST C. S., MURRAY, J. I. and MCCLELLAND, T. H. 1987. Breed and sex differences in equally mature sheep and goats. 3. Muscle weight distribution. *Animal Production* **45:** 277-290.

WALLACE, V. and DAVIES, A. S. 1985. Pre- and post-rut body composition of red deer stags. In *Biology of Deer Production* (ed. P. F. Fennessy and K. R. Drew), *Royal Society of New Zealand, Bulletin 22*, pp. 291-293.

WENHAM, G. and PENNIE, K. 1986. The growth of individual muscles and bones in the red deer. *Animal Production* **42:** 247-256.

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