AN ABSTRACT OF THE THESIS OF

Andrew M. Arnold for the degree of Master of Science in Animal Science presented on September 28, 1987.

Title: Genetic and Environmental Influences on Lamb Carcass Indices and Muscle Fiber Ratios

Abstract approved: Redacted for Privacy

Howard H. Meyer

Two concurrent trials were conducted to examine genetic and environmental influences on growth rate, carcass fatness and muscle fiber type proportions. Trial 1 compared Polypay and Coopworth x Polypay male lambs either left intact or castrated early, mid or late in growth. Trial two compared Hampshire sired lambs (females, early castrated wethers and late castrated wethers) from Suffolk x Coopworth dams and whiteface x Coopworth dams. Half the lambs in each trial were raised from weaning to the standard 52 kg slaughter weight in drylot while the other half were raised to 41 kg on pasture before finishing in drylot. Sex and delaying castration both significantly affected growth rate in Trial 1 but not in Trial 2 and had no effect on feed efficiency in either trial. Rams were leaner than wethers ($P<.001$) which were leaner than ewes ($P<.001$). No significant differences were observed between the sexes in fiber type proportions of the M. longissimus. Late castrates had less carcass fat ($P<.01$) than early

castrates. Early castration increased the proportion of alpha red fibers in Trial 1 ($P<.01$) but had no effect in Trial 2. Substitution of Polypay genes with Coopworth genes did not significantly affect growth rate on either pasture or in drylot and did not alter any of the fatness traits measured. Polypay lambs had a higher proportion of beta red fibers ($P<.05$) than the Coopworth x Polypay lambs. No differences in fiber proportions due to genotype were detected in Trial 2. Lambs grazed on pasture and then finished in drylot had lower growth rates ($P<.01$). They were leaner and had a lower dressing percentage than the lambs fed in the drylot throughout, however, USDA quality grades were similar. Drylot lambs had a higher proportion of beta red fibers, the difference being 5% in Trial 2 ($P<.01$). Single born lambs in Trial 1 had a 6% higher proportion of alpha white fibers ($P<.05$) than the twin born lambs, but this difference was not seen in Trial 2. Muscle fiber proportions were not found to be related to the induced differences in growth and carcass fatness, and no evidence of differential fiber transformation was found in this experiment.

Genetic and Environmental Influences on Lamb Carcass Indices and Muscle Fiber Ratios

by

Andrew M. Arnold

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed September 28, 1987

Commencement June, 1988

Approved:

Redacted for Privacy

Professor of Animal Science in charge of major

Redacted for Privacy

Head of department of Animal Science

Redacted for Privacy

Dean of Graduate School

Date thesis is presented September 28, 1987

Typed by Andrew M. Arnold

ACKNOWLEDGMENTS

I wish to express my sincere appreciation to Dr. H. H. Meyer for his encouragement, guidance, and especially patience, and not necessarily in that order, during my graduate program. Special thanks are extended to Dr. A. R. Menino without whom much of this experiment would not have been possible.

Thanks are expressed to Mr. R. Dickson and Mr. R. Fisher for their unselfish contribution in the slaughter of the lambs and the collection of the carcass data. Plus they brew a mean pot of coffee.

I would like to especially thank Todd Mulrooney and Karen Swanson for their assistance in caring for the lambs, in the collection of data and for just being friends.

Lastly, I am extremely grateful and thankful for the support I received from my family, especially my wife Laurie and daughter Rachel. They provided the strength necessary to undertake and complete a project of this magnitude.

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	1
2.	LITERATURE REVIEW	5
	Summary of Genetic and Environmental Influences on Growth Rate and Feed Efficiency Cattle and Swine	6
	Growth Rate and Feed Efficiency of Sheep	13
	Effect of Sex and Castration	13
	Effect of Genotype	17
	Effect of Feeding Regimen	23
	Summary of Genetic and Environmental Influences on Carcass Traits Composition of Cattle and Swine	25
	Carcass Traits and Composition of Sheep	34
	Effect of Sex and Castration	34
	Effect of Genotype	42
	Effect of Feeding Regimen	50
	Muscle Fiber Type Differentiation	51
	Summary of Genetic and Environmental Effects on Muscle Fiber Type Proportions	54
	Factors Affecting Muscle Fiber Type Proportions of Lambs	61
	Effect of Sex and Castration	61
	Effect of Genotype	61
	Effect of Feeding Regimen	63
3.	EFFECTS OF SEX, TIME OF CASTRATION, GENOTYPE AND FEEDING REGIMEN ON LAMB GROWTH AND CARCASS FATNESS	64
	Abstract	64
	Introduction	65
	Material and Methods	66
	Results and Discussion	70

TABLE OF CONTENTS (continued)

4. INFLUENCE OF SEX, TIME OF CASTRATION, GENOTYPE BIRTHTYPE AND FEEDING REGIMEN ON LAMB MUSCLE FIBER TYPE PROPORTIONS 80

Abstract 80

Introduction 81

Materials and Methods 82

Results and Discussion 84

5. CONCLUSIONS 93

LITERATURE CITED 95

APPENDIX 104

LIST OF TABLES

Table		Page
1.	Summary of Literature Reporting Lamb Growth Rate and Feed Efficiency Influenced by Sex and/or Castration	14
2.	Summary of Literature Reporting Lamb Genotype Effects on Growth Rate and Feed Efficiency	18
3.	Summary of Literature Reporting the Effect of Sex and/or Castration on Lamb Carcass Traits	35
4.	Summary of Literature Reporting Sex and/or Castration on Lamb Carcass Composition	40
5.	Summary of Literature Reporting the Effect of Lamb Genotype on Carcass Traits	43
6.	Summary of Literature Reporting Lamb Muscle Fiber Proportions	62
7.	Experimental Design	67
8.	Adjusted Least Squares Means and Standard Errors For Growth Rate and Feed Efficiency	71
9.	Adjusted Least Squares Means and Standard Errors for Carcass Traits (Trial 1)	74
10.	Adjusted Least Squares Means and Standard Errors for Carcass Traits (Trial 2)	75
11.	Adjusted Least Squares Means and Standard Errors for Slaughter Age, Muscle Fiber Proportions and Yield Grade (Trial 1)	86
12.	Adjusted Least Squares Means and Standard for Slaughter Age, Muscle Fiber Proportions and Yield Grade (Trial 2)	87

GENETIC AND ENVIRONMENTAL INFLUENCES ON LAMB CARCASS INDICES AND MUSCLE FIBER RATIOS

CHAPTER 1

INTRODUCTION

As early as 1964 consumers indicated in an American Sheep Producers Council survey that they preferred their lamb lean. Considerable progress has been made in the reduction of carcass fatness in the last two decades, but millions of pounds of fat are still trimmed from retail meat products. The health consciousness evident today makes production of lean red meat products an industry priority.

Differences in carcass composition of lambs compared at an equal weight are due to differences in the growth rate of muscle and fat. Studies with beef cattle (Berg et al., 1979) and sheep (Jones, 1982) have indicated that females commence deposition of fat at a lighter weight than intact males and are fatter when compared at an equal weight. As carcass fatness increases both subcutaneous and internal fat depots constitute an increasing proportion of carcass fat. Butterfield et al. (1984) found castration to cause increased growth of fat in male sheep. Thus, while rams and wethers commenced fattening at the same time, comparison at an equal weight found wethers to be fatter.

The use of ram lambs has long been advocated as a

means by which to reduce lamb carcass fatness (Robertson, 1966; Turton, 1969). Producers have been reluctant to utilize ram lambs because of potential behavioral problems in pubertal ram lambs reaching sexual maturity and the economic penalty imposed at slaughter. Many of the behavioral problems can be avoided by using genotypes that reach slaughter weight before sexual maturity. The penalty is imposed due to purported lower quality grades, decreased palatability and less desirable carcass weight distribution of ram carcasses. Studies have shown ram lamb carcasses to be commercially acceptable (Crouse et al., 1978; Magid et al., 1981b) and Bradford and Spurlock (1964) found rams to have a higher yield of lean cuts than wethers.

Delaying castration until animals have reached a greater proportion of their slaughter weight may partially realize the superior growth and carcass of ram lambs without economic penalty. Late castration of cattle has been shown to increase ADG and feed efficiency while reducing total carcass fatness when compared to steers castrated before five months of age (Klosterman et al., 1954; Gregory and Ford, 1983; Worrell et al., 1987). Similar results have been obtained by late castration of swine (Bratzler et al., 1954; Charette, 1961). The effects of late castration of lambs are not known.

Butler-Hogg and Johnsson (1986) found that lambs on feeding regimens that cause different growth rates differed

in fatness when compared at an equal weight. The faster growing individual will be fatter provided that food intake is not restricted; differences in growth rate are the result of differences in diet composition and energy level.

Many of the same factors which have been shown to affect growth rate and carcass development have been found to influence muscle fiber type proportions. Moody et al. (1980) working with lambs and Johnston et al. (1981) working with cattle have shown proportions of the three fiber types to differ between the sexes. These studies also found proportions of alpha red and alpha white fibers to be affected by feeding regimen.

Genotype has also been shown to significantly affect muscle fiber proportions of lambs (Solomon et al., 1981), swine (Miller et al., 1975) and cattle (May et al., 1977).

Using multiple biopsies over the life of cattle, Cornforth et al. (1980) found muscle fiber type proportions to change during growth. Animals are born with predominantly beta red and alpha red fiber types. As growth progresses, an increase is seen in the proportion of alpha white fibers. Since alpha red fibers have the capacity to become alpha white fibers and postnatal increase in muscle size is largely through hypertrophy, not hyperplasia (Beitz, 1985), Ashmore et al. (1972) postulated that the increase in proportion of alpha white fibers was the result of transformation of alpha red fibers to alpha

white fibers.

Hawkins et al. (1985b) concluded that this transformation occurred shortly before lambs reached slaughter weight and the ratio of alpha red to alpha white fibers was representative of physiological maturity. They found alpha red fiber proportion to be positively correlated to muscle indices and negatively correlated to fat indices and age. The opposite was found for the proportion of alpha white fibers.

This study was initiated to examine the effects of sex, time of castration, genotype, and feeding regimen on lamb growth, carcass development, and muscle fiber type proportions. Both growth rate and carcass fatness influences on muscle fiber type proportions were examined, to see whether there existed a quantifiable relationship.

CHAPTER 2

LITERATURE REVIEW

The livestock industry future depends on the efficient production of quality meat products that are free of excess fat. Increased profits from livestock production may be realized by increasing daily liveweight gain and feed efficiency while maintaining carcass composition, quality and palatability acceptable to the consumer. One method to accomplish this is use of intact males. Intact males gain more rapidly and efficiently, producing higher yielding carcasses. In the past, castration has been utilized to minimize problems such as less intramuscular fat and what was perceived as inadequate subcutaneous fat in intact male carcasses. However, today's consumer demand for lean red meat products appears to render the need for castration obsolete.

Removal of the testes reduces production of the males' natural anabolic steroids, testosterone and estrogen. Growth rate of the castrate is usually less than for intact males (Unruh, 1986). Turton (1969) observed that the age at which cattle, sheep or swine are castrated will have a profound influence on the effect of castration. Delaying castration in farm animals beyond the age at which it is commonly practiced has been suggested as a means of benefiting from the efficiency of entire male growth without suffering the economic penalties imposed at

marketing (Robertson, 1966).

The majority of research looking at the effects of delayed castration on growth and carcass composition has been done with cattle and swine. No literature is available on the effects of delayed castration on lambs. Thus, for the purpose of this review and to give greater insight into the effects of sex, castration time, genotype and feeding regimen on growth and development of the major meat species, data for cattle and swine will be presented as well.

SUMMARY OF GENETIC AND ENVIRONMENTAL INFLUENCES ON GROWTH RATE AND FEED EFFICIENCY OF CATTLE AND SWINE

Growth rate, measured as average daily gain (ADG), is affected by many factors. Hedrick et al. (1969) found in beef cattle that bulls gain approximately 19% faster than heifers. Comparison of bulls (intact) and steers (castrates) shows that bulls outgain steers by an average of 12% (Klosterman et al., 1954; Gregory and Ford, 1983; Worrell et al., 1987). Rate of gain between early and late castrated cattle does not vary by more than 10% and does not always favor the later castrated animals (Klosterman et al., 1954; Gregory and Ford, 1983: Worrell et al., 1987). Gregory and Ford (1983) found bulls' daily gain to be as much as a third greater than for the late castrates.

Cattle genotypes differ in growth rate by as much as 25% (Trenkle et al., 1978; Gregory and Ford, 1983). The

greatest differences are seen when comparing small framed breeds with large framed breeds. This is especially true at heavier slaughter weights (>500 kg).

Growth rate of cattle is also influenced by feeding regimen. Steers finished on pasture may have daily gains that are one-third less than comparable steers finished in the feedlot. Concentrate supplementation of pasture-finished steers increases growth rate, but gains are still approximately 10 to 15% less than for feedlot steers. When high quality forages are grazed without supplemental feeds, gut fill may limit the growing and finishing animal from consuming the energy necessary for maximum gains. A nutrient imbalance is created, resulting in a waste of valuable protein (Utley and McCormick, 1976). Comparison of pasture finished cattle to feedlot finished cattle shows that growth rate of bulls is retarded more by the reduced plane of nutrition than is that of steers (Robertson, 1966; Turton, 1969).

Sex effects on the growth rate of swine are less than those seen with cattle. Overall daily gain differences between boars, barrows and gilts are minimal-rarely exceeding 5%-with no one sex showing a clear advantage (Bratzler et al., 1954; Charette, 1961; Prescott and Lamming, 1964; Blair and English, 1965; Turton, 1969).

Delayed castration of swine reduces the sex effect on ADG. Differences are minimal, varying by no more than 2%

between boars, gilts and barrows (Bratzler et al., 1954; Charette, 1961). Lack of a sex effect could be due to a shorter finishing period for swine than for cattle.

Genotypic differences in ADG of swine vary between 5 and 10% (Bowland and Berg, 1959; Turton, 1969). Reduced genotypic variation of swine compared to beef cattle is likely due to the more prevalent use of crossbreeding and rotational crosses with swine than with cattle.

Growth rate can be affected by combinations of the above factors as well. Bowland and Berg (1959) found ADG to be influenced by the interaction of genotype and sex; gilts of particular genotypes had superior gains.

Feeding effects on swine growth are exerted more by ration composition than by different management regimens. Prescott and Lamming (1967) found a significant interaction between castration and level of dietary protein. Boars fed a high protein diet (19.6% protein until 68kg, then 15.7% protein) gained 8% faster than barrows fed the same diet. When fed a standard level of protein diet (17.2% protein until 68kg then 13.8% protein) boars gained less than 1% faster than barrows. Thus, the superiority in potential growth rate of boars over barrows and gilts may be retarded by a lack of protein in diets designed to meet the needs of barrows and gilts.

To briefly summarize genetic and environmental influences on growth rate of cattle and swine: sex affects ADG of cattle, with bulls superior to steers which are

superior to heifers. It has little influence on ADG of swine, with no one sex having a consistent advantage. Delaying of castration does little to change the growth rate of cattle, but improves the growth rate of male swine. Genotypic effects on ADG in cattle are greatest between breeds of different frame size. Genotypic differences in ADG are minimal in swine. Feeding regimen influences cattle growth; animals on forage regimens have a lower ADG than animals in drylot. Ration composition, not feeding regimen, influences ADG of swine.

Feed efficiency is a function of daily intake and daily gain (Herriman et al., 1977). Much of the research looking at gain and feed efficiency has found a high correlation between the two traits. The high correlation has provided a hope that selection programs based on gain would lead to improvement in the ability of an animal to both gain weight and use feed efficiently. This premise is based on the assumption that the correlation has a genetic basis. Sutherland (1965), working with mice, found both genetic and phenotypic correlations of gain and feed per unit gain to be high. He concluded that the ratio was a valid estimate of energetic conversion efficiency (a biological function). Gunsett et al. (1981) found selection for either increased gain on a fixed amount of feed or for decreased feed intake on a constant gain were equally effective in improving growth rate and efficiency

of feed utilization in mice.

Feed efficiency can be measured in the broad sense by either feed per unit gain or by the inverse, gain per unit feed. Feed efficiency can also be expressed as total digestible nutrients (TDN) per unit gain, or as metabolizable energy (ME) per unit gain. These latter ratios are more accurate measurements of an animal's efficiency and should not vary with diets of different feedstuffs.

Feed efficiency in cattle normally varies between the sexes by 10 to 20% (Klosterman et al., 1954; Prescott and Lamming, 1964; Robertson, 1966; Turton, 1969; Worrell et al., 1987). Gregory and Ford (1983), however, found bulls to be 40% more efficient than steers in feed conversion. The higher the energetic density of the diet the greater is the difference between sexes in feed efficiency (Trenkle et al., 1978). Normally bulls are the most efficient, followed by steers and then heifers. Hedrick et al. (1969), however, found differences in feed efficiency between steers and heifers to be negligible.

Feed efficiency is not affected by time of castration in cattle. Bulls are superior to either early or late castrates by approximately 20% (Klosterman et al., 1954; Worrell et al., 1987). Steers castrated at intervals between 70 and 410 kg show less than 10% variation in feed efficiency, and animals castrated the latest are not necessarily the most efficient (Worrell et al., 1987).

Gregory and Ford (1983) found differences in feed efficiency due to genotype to range from 10 to 15%. The largest differences were seen in comparisons between the large and small framed breeds.

Sex exerts a slight influence on feed efficiency of swine. Boars are the most efficient in feed conversion followed by gilts with barrows the least efficient. The range of difference between the three sexes rarely exceeds 12% and can be as little as 1 to 2% (Bowland and Berg, 1959; Charette, 1961; Blair and English, 1965).

Charette (1961) found early and late castrated barrows differed by approximately 10% in feed efficiency with the late castrates being more efficient. Overall difference between boars and barrows was 11%, but the difference between boars, and barrows castrated at 88% of slaughter weight was only 3%. Gilts had a 5% superiority over an average of both early and late castrates, but no advantage when compared to only the late castrates.

Bowland and Berg (1959) found feed utilization differences between Yorkshire, Lacombe x Yorkshire, Yorkshire-Lacombe x Yorkshire backcross and a three way cross of Tamworth x Lacombe x Yorkshire to range from 10 to 15%.

In conclusion, sex influences feed efficiency in both cattle and swine. The differences seen between the sexes are greater in cattle than they are in swine. Bulls are

the most efficient followed by steers and then heifers while boars are the most efficient swine followed by gilts and barrows. Delaying castration has no effect on feed efficiency in cattle, but delaying castration of swine increases feed efficiency by approximately 10%. Genotypic differences for feed efficiency of both cattle and swine range from approximately 10 to 15%.

GROWTH RATE AND FEED EFFICIENCY OF SHEEP

Effect of Sex and Castration

Sex effects on ADG are highly variable in lambs (Table 1). Rams have approximately 17% higher ADG than ewes (Preston et al., 1960; Garrigus et al., 1962; Glimp, 1971; Shelton and Carpenter, 1972; Adams et al., 1977; Makarechian et al., 1977; Butler-Hogg et al., 1984). Herriman et al. (1978) found rams to have a 50% advantage in ADG compared to ewes managed under intensive feedlot conditions and fed a ration comprised almost entirely of concentrate. On average, rams grow 12% faster than wethers (Hunt et al., 1938; Preston et al., 1960; Garrigus et al., 1962; Bradford and Spurlock, 1964; Prescott and Lamming 1964; Prescott, 1969: Glimp, 1971; Shelton and Carpenter, 1972; Makarechian et al., 1977; Lloyd et al., 1980). The males' advantage over females in growth rate is reduced by castration, averaging only 5%. The difference in ADG seen between ewes and wethers is the most consistent of the sex comparisons ranging from 0 to 9% (Preston et al., 1960; Garrigus et al., 1962; Glimp, 1971; Shelton and Carpenter, 1972; Makarechian et al., 1977).

Measurement of growth rate as carcass weight gain per day of age (CW/DA) shows the same trends as for ADG. Garrigus et al. (1962) found rams to have a 15% advantage over ewes in CW/DA in one year, but no difference was apparent the next year. This was attributed to

Table 1. Summary of Literature Reporting Lamb Growth Rate and Feed Efficiency as Influenced by Sex and/or Castration

Reference	Special Conditions	n			ADG(Kg)[2]			Feed[2] Efficiency		
		R	W	E[1]	R	W	E	R	W	E
Hunt (1938)		27	25	-	.17	.16	-	(Kg feed/Kg gain) 9.7	8.8	-
Preston (1960)		9	8	15	.35	.33	.31			
Garrigus (1962)	1957	-	14	12	-	.34	.32			
	1959	30	23	49	.29[d]	.25[e]	.23[f]			
	1960	27	26	43	.25[a]	.24[b]	.24[b]			
Bradford (1964)	pre-weaning	145	106	-	.25[d]	.24[e]	-			
Prescott (1964)		6	6	-	.11	.09	-			
Prescott (1969)	low energy	8	8	-	.34[a]	.30[b]	-	(Mcal ME/Kg gain) 13.7[a]	15.3[b]	-
	high energy	8	8	-	.34	.34	-	13.3	13.2	-
Glimp (1971)	pre-weaning	118	109	432	.28[d]	.25[e]	.24[f]			
	post-weaning	91	101	-	.28[d]	.25[e]	-			

(cont.)

Table 1 (cont.). Summary of Literature Reporting Lamb Growth Rate and Feed Efficiency as Influenced by Sex and/or Castration

Reference	Special Conditions	n			ADG(Kg)[2]			Feed[2] Efficiency		
		R	W	E[1]	R	W	E	R	W	E
Shelton (1972)		53	49	48	.29[d]	.24[e]	.23[f]	(Kg feed/Kg gain) 5.8[d]	6.4[e]	6.8[f]
Adams[3] (1977)	32-45Kg	10	-	10	.37	-	.32	5.3	-	7.3
	45-57Kg	10	-	10	.28	-	.21	6.5	-	8.8
Makarechian (1977)		81	81	81	.33[a]	.28[b]	.26[b]			
Herriman[3] (1978)	32-45Kg	30	-	30	.39	-	.26	5.2	-	7.8
	45-57Kg	30	-	30	.33	-	.22	6.8	-	9.6
Lloyd (1980)		46	40	-	.28[d]	.22[e]	-			
Butler-Hogg (1984)		15	-	15	.28[a]	-	.25[b]			

1 R=Rams; W=Wethers; E=Ewes

[2]different superscripts within a row within a study differ a,b,c $p<.05$; d,e,f $P<.01$

[3]data was not tested statistically

environmental differences between the two years. The differences between rams and wethers in CW/DA are not as great as those seen in ADG. A greater proportion of the intact males' liveweight is comprised of head, organ, and testes weights (Butterfield et al., 1985). Rams show an approximately 5% greater carcass weight per day of age than wethers (Garrigus et al., 1962; Kemp et al., 1970). Superiority of wethers to ewes in CW/DA averages 5-6% (Garrigus et al., 1962; Hawkins et al., 1985).

In studies comparing rams to ewes, rams required approximately 29% less feed per unit gain (Adams et al., 1977; Herriman et al., 1978). Shelton and Carpenter (1972), in a trial involving rams, wethers and ewes, found rams to have a 10% better feed efficiency than wethers which were 6% more efficient than ewes. Castration reduces the feed efficiency of males by approximately 10% (Shelton and Carpenter, 1972; Prescott, 1969).

In 1938, Hunt et al. reported wethers to be 10% more efficient than rams. However, the feed efficiency of their sheep was 30% less than any of the more recent values cited. The difference is likely due to sheep of the earlier time period being earlier maturing. Given the heavy slaughter weights of these animals (55 kg), and the known reduction in feed efficiency at heavier weights, the reported results are not unexpected. Prescott (1969) found rams and wethers raised on high concentrate rations (>80% concentrate rations) from shortly after birth to slaughter

did not differ in feed efficiency, unlike rams and wethers fed low energy diets until the finishing period. The lambs were slaughtered at relatively light weights (44kg) for their genotype (Suffolk sires x Border Leicester x Cheviot dams). Thus it is likely that if the lambs had been allowed to reach heavier weights, greater differences in feed efficiency may have been expressed.

Rams have a higher ADG than wethers which gain faster than ewes. Castration reduces the intact males' growth advantage. Differences in feed efficiency follow the same trends as seen in ADG; however, differences appear to be reduced on high concentrate diets.

Effect of Genotype

The genotypes involved in this research were Polypay, Coopworth, and blackface crosses. Thus, for the purpose of this review, the effects of genotype will be limited to examining these particular genotypes. The data for ADG of these genotypes is presented in Table 2 and provides the basis for the conclusions presented here.

The Polypay and Coopworth breeds are composite genotypes. The Polypay was developed at the USDA Sheep Experiment Station, Dubois, and is comprised of equal proportions of Rambouillet, Targhee, Dorset and Finnish Landrace (Finn) (Hulet et al., 1984). The Rambouillet and Targhee breeds were used to contribute wool quality and hardiness under western range conditions. Dorset genes

Table 2. Summary of Literature Reporting Lamb Genotype Effects on Growth Rate and Feed Efficiency

Reference	Breed[1]	n	ADG[2](Kg)	Feed[2] Efficiency (Kg feed/Kg gain)
Butcher (1962)	BF	64	0.18	8.2
	WF	64	0.17	8.4
				(Kg gain/Kg feed)
Doney (1967)	Scottish BF (25% inbred)	4	0.17[x]	0.13[x]
	Scottish BF (outbred)	4	0.23[y]	0.15[y]
Jagusch (1971)	Dorset x Coopworth	38	0.29[x]	
	Dorset x Romney	63	0.27[y]	
Craddock (1972)	BF	49	0.20	
	WF	48	0.20	
Dalton (1974)	Romney	39	18.00[a]	
	Corriedale	39	18.80[a]	Total gain (Kg)
	Perendale	39	21.20[b]	birth to weaning
	Border Leicester x Romney	39	22.10[c]	
Dahmen (1977)	Suffolk x Panama	28	0.26[x]	
	Suffolk x Panama x Finn	29	0.25[y]	

(cont.)

Table 2 (cont.). Summary of Literature Reporting Lamb Genotype Effects on Growth Rate and Feed Efficiency

Reference	Breed[1]	n	ADG[2](Kg)	Feed[2] Efficiency (Kg feed/Kg gain)
Makarechian (1977)	Dorset	81	0.27[a]	
	Suffolk	81	0.32[b]	
Lloyd (1980)	BF	45	0.29[x]	
	WF	41	0.23[y]	
Crouse (1981)	Suffolk x Fx	78	0.20[a]	
	Ramboulliet x Fx	75	0.20[b]	
Magid (1981a)	Border Leicester	293	0.19[a]	
	Finn	346	0.18[b]	
Collins (1982)	Polypay	28	0.26	8.9 (6)[3]
	Dorset	23	0.26	8.2 (6)
	Border Leicester	19	0.27	8.3 (6)
	Suffolk	24	0.27	7.8 (6)
Hulet (1984)	Targhee	217	0.26	
	Dorset x Targhee	222	0.24	
	Finn x Ramboulliet	290	0.23	
	Polypay	277	0.24	
Lirette (1984)	Suffolk	10	0.26[a]	
	Finn	10	0.20[b]	

[1]BF=blackface; WF=whiteface; Finn=Finnish Landrace; Fx=Finn cross
[2]different superscripts within a column within a study differ a,b,c P<.05; x,y,z P<.01
[3]sample size=6

contribute to growth rate, carcass quality, and milking ability of the ewes. The Finn was used to increase fertility. The Polypay was primarily developed as a ewe breed to increase prolificacy of western range flocks and most research has been directed at ewe production. Thus, little data is available on growth rate and feed efficiency.

The Coopworth is the result of crossing Border Leicesters with Romneys and is comprised of 50% from each breed. The Coopworth was developed in New Zealand for production from pasture and only recently have a limited number been imported into the United States. Therefore, no previous research has been done with Coopworths in the United States.

Results comparing the Polypay foundation breeds with Suffolks (a high growth rate breed) indicate the Polypays' growth rate is likely to be lower than the Suffolks'. Finns had a 25% lower ADG compared to Suffolks (Lirette et al., 1984). Similarly Dorsets have been found to make daily gains 19% lower than for Suffolks (Makarechian et al., 1977). Comparison of Suffolk-sired lambs produced by Panama and Finn x Panama dams found the substitution of Finn genes produced a 7% reduction in ADG (Dahmen et al., 1977). Comparison of the progeny resulting from Rambouillet and Suffolk sires mated to Finn cross dams found the Rambouillet crosses to have daily gains averaging 5% less than for Suffolk crosses (Crouse et al., 1981).

Hulet et al. (1984) found Polypay lambs compared to their foundation stock had a 4% greater ADG than inter se mated Finn x Rambouillet, but were slightly inferior to inter se mated Dorset x Targhee. The authors also compared Polypay to straightbred Targhees and found Polypays' to have an 11% lower ADG. Polypay cross lambs were found not to differ in ADG compared to Dorset cross lambs under feedlot conditions (Collins, 1982). Under the same conditions, Suffolk cross lambs were found to have 4% higher ADG than the Polypay crosses.

Under New Zealand conditions, crosses involving the Coopworth and its foundation breeds demonstrate it to be a high growth rate sheep. Dalton and Ackerly (1974) found Border Leicester x Romney lambs to average 15% higher total gains from birth to weaning (approximately 120 days) compared to Perendale, Corriedale and Romney, the primary breeds of New Zealand. Dorset x Coopworth lambs matings had 4% greater daily gains than Dorset x Romney lambs (Jagusch, 1971). In the United States under drylot conditions, Border Leicester cross lambs were found to have a 9% advantage in ADG compared to Finn cross lambs (Magid et al., 1981a). Under similar drylot conditions, Collins (1982) found Border Leicester crosses to have 4% higher ADG than Polypays.

In comparison of trials involving blackface and white face genotypes, blackface lambs average 12% higher daily

gains than whiteface lambs (Butcher and Raleigh, 1962; Makarechian et al., 1977; Lloyd et al., 1980; Crouse et al., 1981). One reported exception was that of Craddock, Field, Riley and Botkin (1972) as cited in Botkin and Cramer (1974) who found no difference in daily gains between Suffolk crosses and Columbia crosses. This might be explained by the Columbia breed developing as a terminal sire for western range flocks due to the Suffolk being poorly suited to the environment. Columbias have been selected for high growth rate and carcass merit, thus differ less from the Suffolk than do most whiteface breeds.

Little feed efficiency data is available for sheep in general, and specifically for the Polypay and Coopworth breeds, due to the forage management schemes under which they are typically reared. Collins (1982) found Polypay crosses to require 7%, 9% and 11% more feed per kilogram gain than Border Leicester, Dorset and Suffolk crosses, respectively. It is generally regarded that blackface breeds require less feed per unit gain than do the whiteface breeds, though differences are often negligible. Butcher and Raleigh (1962) found blackface cross lambs to be 2% superior in feed efficiency to whiteface cross lambs. Differences in feed efficiency can also exist in genotypes within breeds. Doney (1967), using inbred (inbreeding coefficient 25%) and outbred Scottish Blackface sheep, found inbred individuals to need 16% more feed per unit gain than did the outbred individuals.

Due to the fact that the Coopworth might be slightly better adapted than the Polypay to the pasture management of Oregon, they should be expected to have slightly higher ADG. While ADG of Polypays and Coopworths will be similar, they will be considerably below gains of the Suffolk. The Polypay is likely to be more feed efficient than the Coopworth. Blackface crosses should outgain and be better utilizers of feed than whiteface crosses.

Effect of Feeding Regimen

Lambs finished on pasture gain from 28% (Ely et al., 1979) to 56% less (Purchas, 1978) per day than lambs finished under feedlot conditions. In the trial by Ely et al. (1979), gains of pasture lambs supplemented with a 13% crude protein concentrate ration were 12% less than lambs in the feedlot, however, the difference was not significant. The lambs on pasture used 40% less concentrate than feedlot lambs per pound of gain.

Herbage allowance is the major factor limiting lamb gains on pasture (Jagusch et al., 1979; Thompson et al., 1980; Hodgson, 1984). Thirty kilogram lambs under New Zealand conditions need a minimum herbage allowance of 3kg DM/hd/day to achieve gains of 80-100g/day (Thompson et al., 1980). Liveweight gains will increase with increasing herbage allowance. Jagusch et al. (1979) found maximum gains of 150g/hd/day will be attained at allowances of 5kg DM/hd/day. Pasture yield has little effect on the rate of

gain provided lambs are given the same allowance in low yielding pastures as in high yielding pastures (ie. managed at lower stocking densities). Maximum intake is usually achieved at allowances 3-4 times greater than amount consumed. Intake declines when allowance is less than twice intake (Hodgson, 1984). Reduced allowance may force lambs to eat plants with a lower digestibility. At greater allowances a lesser proportion of the pasture is utilized, so lambs are managed to balance gain with forage allowance to best utilize pastures.

SUMMARY OF GENETIC AND ENVIRONMENTAL INFLUENCES ON CARCASS TRAITS AND COMPOSITION OF CATTLE AND SWINE

Differences in age or weight of animals at slaughter can cause carcass composition to differ significantly between the different age or weight groups. Differences due to sex, genotype and feeding regimen can also profoundly influence the various carcass traits.

Much of the difference between bulls and heifers in carcass composition is in fatness. Hedrick et al. (1969) in a comparison of bull and heifer carcasses found heifers to have 30% greater subcutaneous fat depth over the M. longissimus, approximately 9% more fat trim and nearly double the percentage ether extract in the M. longissimus. Bulls had a 15% larger REA than heifers. Much of the ribeye difference is attributable to the 50 kg advantage in average carcass weight of bulls at the same age. Trenkle et al. (1979) found cattle slaughtered at heavier weights had larger ribeye areas. The heavier and leaner carcasses of the bulls points to the fact that heifers commence fat deposition earlier than bulls (Berg et al., 1979)

Steers have been found to have approximately 12% more carcass fat than bulls (Prescott and Lamming, 1964). Comparison was made at a constant age and bull carcasses averaged 11 kg heavier than the steer carcasses. Hedrick et al. (1969) found steer carcasses to have 5% more fat trim and 3% more fat in the M. longissimus than bull carcasses averaging 35 kg heavier. Steers have 10 to 40%

greater subcutaneous fat depth over the M. longissimus (Prescott and Lamming, 1964; Hedrick et al., 1969; Ockerman et al., 1984; Worrell et al., 1987) with extremes of as much as 70% more (Gregory and Ford, 1983). Steers have 20 to 30% more kidney pelvic and heart fat (KPH) when calculated as a proportion of carcass weight. Percentage of fat in the M. longissimus is higher for steers than bulls and steers consistently have higher marbling scores (Gregory and Ford, 1983; Ockerman et al., 1984; Worrell et al., 1987). Bulls have approximately 5% greater muscle development than steers (Prescott and Lamming, 1964). This is evidenced by their 10 to 20% superiority in ribeye area (Hedrick et al., 1969; Gregory and Ford, 1983; Ockerman et al., 1984; Worrell et al., 1987). However, some of the difference can be attributable to heavier slaughter weights, and hence greater muscle development, of the bulls (Trenkle et al., 1978). Bulls have lower USDA yield grades indicating a 1 to 3% advantage in retail cuts (Ockerman et al., 1984; Worrell et al., 1987).

Delayed castration modifies the difference in fatness between bulls and steers. Klosterman et al. (1954) found total carcass fat differences are reduced, with late castrate steers only 4% fatter than bulls. Late castrate steers have approximately 8% greater fat depth and 17% more KPH than do bulls (Gregory and Ford, 1983; Worrell et al., 1987). Yield grade difference between steers and bulls is

reduced by delayed castration. Bulls have a 1% superiority in percentage retail cuts (Worrell et al., 1987). The reduced fatness is also reflected in lower marbling scores of bulls and late castrates (Klosterman et al., 1954; Gregory et al., 1983; Unruh, 1986). Since quality is equated with marbling, bulls and late castrates often do not grade choice.

Hammond (1920) found late castrates had a greater weight of the carcass in hindquarters compared to bulls. However, this difference is due to additional subcutaneous and kidney fat in the hindquarter of the steer (Klosterman et al. 1954; Prescott and Lamming, 1964). Delaying castration does not modify muscling differences between bulls and steers (Gregory and Ford, 1983; Worrell et al., 1987).

The general consensus is that bull carcasses are the leanest followed by steers and then heifers. This comparison is usually made at a constant weight or age. From this comparison it is apparent that heifers commence fat deposition at an earlier age and a lighter weight than steers of the same genotype. Likewise steers commence fat deposition earlier and at a lighter weight than bulls (Berg et al., 1979). It has been determined that growth of total fat per carcass side and growth of depot fat relative to total muscle is similar for steers and heifers and less for bulls. Comparison of the fat depots, especially subcutaneous and intermuscular, at a constant weight of

total fat shows no difference between the sexes (Jones et al., 1980). Thus, it appears that fatness differences being expressed between the sexes are a function of an earlier onset of the fattening phase with respect to muscle weight in heifers compared to steers and steers compared to bulls (Berg et al., 1979; Jones et al., 1980).

Genotype exerts more effect on carcass fatness than on muscling. Subcutaneous fat measured over the M. longissimus at the 12th rib differs between genotypes by as much as 50%. Internal fat (KPH) differences are less than 15%. Intramuscular fat is highly variable; at 500 kg liveweight some genotypes have only a trace amount of marbling while other genotypes have a moderately abundant amount of marbling. Ribeye area varies by approximately 6% between genotypes (Peacock et al., 1979; Gregory and Ford, 1983). Gregory and Ford (1983) also found dressing percentage to vary by as much as 4% between genotypes.

Even at slaughter weights of 500 kg, many of the large frame genotypes lack the intramuscular fat necessary to grade choice. This is not due only to differences between genotypes in the onset of the fattening stage, but can also be attributed to genotypic variation in the ratios of fat depots at a constant total body fat. The largest fat differences between genotypes are seen in the subcutaneous and intermuscular depots, explaining the large variation in subcutaneous fat depth over the M. longissimus (Jones et

al. 1980).

Manipulation of the feeding regimen produces differential fat deposition in beef cattle. Bowling et al. (1977), in a comparison of forage fed and grain fed cattle of equal USDA quality grades, found carcass weight of the forage fed animals to be 13 kg lighter. Forage fed cattle had 50% lower subcutaneous fat depth, proportion of KPH was reduced 36%, and no difference was seen in intramuscular fat compared to the grain fed animals. Ribeye area of the forage fed cattle was 15% smaller, and the slight advantage in percentage of retail cuts of the forage fed animals was offset by their lower carcass weight.

A comparison of pasture fed and feedlot fed cattle (Utley and McCormick, 1976) slaughtered at a constant age found the feedlot cattle to have approximately 30 kg heavier carcasses and 44% greater subcutaneous fat depth. Feedlot cattle had slightly more intramuscular fat and a lower percentage of retail cuts (51 vs. 52%). In the same study, feedlot cattle compared to cattle on pasture supplemented with concentrates had 15 kg heavier carcasses and 36% more subcutaneous fat depth, when slaughtered at a constant age. The pasture fed cattle had a slightly higher percentage of retail cuts which was offset by their lower carcass weight.

Hedrick et al. (1983) in a comparison of cattle produced on either pasture or corn and slaughtered at a constant age, found the pasture cattle to be high yielding

with little fat. Their carcasses did not grade choice, however, and had smaller ribeye areas. A post pasture feeding period of 120 days increased ribeye area concomitantly with weight.

Summarizing the differences in carcass traits of cattle due to genetic and environmental influences finds bulls to be the leanest, followed by steers and then heifers when slaughtered at an equal weight. This is due to differences in the onset of fattening between the sexes. Heifers deposit fat at a lighter weight than steers and steers at a lighter weight than bulls. Bulls are more heavily muscled than heifers and steers. Delaying castration reduces fatness differences, but not muscling differences, seen between bulls and early castrated steers. Both bulls and late castrates have only a small amount of intramuscular fat and often do not make the USDA choice grade. Genotypic differences in carcass traits are usually the largest between large and small framed genotypes. The genotypic differences have a greater effect on carcass fatness than on muscling. This is due not only to differences between breeds in the onset of fattening, but also genotypic variation in the ratios of the various fat depots at a constant body fat. Pasture feeding reduces carcass fatness and results in higher yield grades than concentrate feeding. However, with the present USDA quality grading system most of the pasture-fed cattle do

not grade choice.

As with cattle, the greatest influence of sex on swine carcass development is exerted on the fat depots. Leaness differences between the sexes begin to show most obviously after hogs reach 68kg (Cahill et al., 1960). Gilts average 6 to 10% greater subcutaneous backfat thickness than boars. Dressing percentage is 1 to 2% higher for gilts. Loin-eye areas are approximately the same for boars and gilts (Bowland and Berg, 1959; Cahill et al., 1960; Charette, 1961; Blair and English, 1965).

Both boars and gilts have leaner carcasses than barrows. Subcutaneous fat depth of barrows is 10 to 20% greater than boars and 6 to 10% greater than gilts. Loin eye area of barrows averages 5 to 10% smaller than for boars and gilts (Bowland and Berg, 1959; Charette, 1961; Prescott and Lamming, 1964;) with extremes of 20 to 25% smaller (Cahill et al., 1960; Blair and English, 1965). Prescott and Lamming (1964) examining the carcass composition of barrows and boars, found barrows to have 4% less lean and 9% more fat.

Delaying castration reduces carcass fatness of swine. Castration, at greater than 80% of slaughter weight reduced backfat depth by 15 to 20% when compared to early (<4 weeks) castration (Bratzler et al., 1954; Charette, 1961). Late castrates compared to boars still have approximately 15% greater backfat thickness. The superiority of the gilts when compared to the early

castrates is greatly diminished when compared to late castrates. The difference in backfat thickness is reduced to approximately 2%. Late castration also reduces differences in loin-eye area, with all three sex groups being approximately equal (Bratzler et al., 1954; Charette, 1961). Bratzler et al. (1954) also found late castrates had a higher percentage of preferred cuts and percentage of lean in loin eye cross-section than did early castrates. Percentage of lean in the loin eye cross-section was found to be highly correlated (r=0.86) to carcass cut out.

Bowland and Berg (1959) using Yorkshire, Lacombe x Yorkshire, Lacombe x Yorkshire x Yorkshire backcross and Tamworth x Lacombe x Yorkshire rotational cross, found differences in dressing percentage to be minimal (<1%) between genotypes. Loin-eye area differed by approximately 5% between genotypes. Differences in backfat thickness between genotypes were highly variable, ranging from 1 to 18%. Much of the fatness variation can be attributed to differential onset of fat deposition between breeds. Variation in the amount of fat partitioned to the fat depots at a constant weight of total fat between breeds is less than 10% (Wood, 1982). Thus fat distribution between the genotypes is similar.

In summary, boars are leaner than gilts which are leaner than barrows. Muscling differences between boars and gilts are minimal, and boars and gilts are more heavily

muscled than barrows. Delayed castration reduces carcass fatness of the castrates. Barrows castrated at greater than 80% of slaughter weight have only slightly more backfat than gilts. Late castration minimizes loin eye area differences between castrates compared to both boars and gilts. Fat distribution between genotypes is similar; fatness differences are largely due to differential onset of fat deposition between breeds.

CARCASS TRAITS AND COMPOSITION OF SHEEP

Effect of Sex and Castration

The major difference between ram and ewe carcasses is in fatness (Table 3). Ewes average 60% greater subcutaneous fat depth over the M. longissimus at the 12th rib (Oliver et al., 1967; Shelton and Carpenter, 1972; Adams et al., 1977; Herriman et al., 1978; Crouse et al., 1978; Magid et al., 1981b) and 54% more kidney-pelvic (KP) fat when measured as a proportion of carcass weight (Shelton and Carpenter, 1972; Adams et al., 1977 Crouse et al., 1978; Herriman et al., 1978; Magid et al., 1981b). This additional fat is the major reason that ewes have a 3% higher average dressing percentage (Shelton and Carpenter, 1972; Adams et al., 1977; Herriman et al., 1978; Magid et al., 1981b). Sex differences in muscling as indicated by ribeye area and legscore are much less than differences in the fat indices. Rams have a 5% larger ribeye area (Oliver et al., 1967; Shelton and Carpenter, 1972; Adams et al., 1977; Herriman et al., 1978; Crouse et al., 1978) with no appreciable differences seen in legscore (Magid et al., 1981b). Ewe and ram carcasses both have similar USDA quality grades with ewe carcasses averaging one-third of a grade higher (Shelton and Carpenter, 1972; Adams et al., 1977; Herriman et al., 1978; Crouse et al., 1978; Magid et al., 1981b). Based on yield grade differences, rams produce a higher cutability carcass with a 2% superiority

Table 3. Summary of Literature Reporting the Effect of Sex and/or Castration on Lamb Carcass Traits

Reference	Sex[1]	n	CCW (Kg)	Dressing %	Fat Depth	% KP	REA (cm^2)	Leg[2] Score	USDA[2] Quality Grade	USDA[3] Yield Grade
Hunt	R	27	18.0	47.4						
(1938)	W	25	18.0	49.5						
Oliver	R	112			4.6[a]		12.5[a]			
(1967)	W	90			4.6[a]		12.3[a]			
	E	135			5.8[b]		11.9[b]			
Kemp	R	30	21.8	48.4	5.2[x]	2.3				
(1970)	W	30	22.6	50.0	8.0[y]	2.7				
Glimp	R	91		48.4[a]					9.0[a]	
(1971)	W	101		49.5[b]					10.0[b]	
Shelton	R	53		53.9[a]	5.1[a]	2.4[a]	14.5[a]		12.3	3.1[a]
(1972)	W	49		54.7[b]	8.2[b]	2.9[b]	13.6[b]		12.0	3.6[b]
	E	48		57.5[c]	8.4[b]	4.7[c]	13.2[c]		13.3	4.2[c]
Dahmen	W	31	23.8	50.1	5.5[x]	3.0[x]	13.5	12.4	11.8[a]	3.3[x]
(1977)	E	26	23.5	50.3	7.8[y]	3.7[y]	13.1	12.5	12.1[a]	3.8[y]
Adams[4]	R	20		50.4	5.3	3.4	14.8		11.7	3.3
(1977)	W	20		54.6	9.9	4.7	13.2		13.3	4.2
Crouse	R	68	20.8		2.9[x]	1.5[x]	13.9[x]			2.7[x]
(1978)	E	70	18.5		4.2[y]	2.3[y]	12.5[y]			3.5[y]

(cont.)

Table 3 (cont.). Summary of Literature Reporting the Effect of Sex and/or Castration on Lamb Carcass Traits

Reference	Sex[1]	n	CCW (Kg)	Dressing %	Fat Depth	% KP	REA (cm^2)	Leg[2] Score	USDA[2] Quality Grade	USDA[3] Yield Grade
Herriman[4]	R	60		50.2	5.6	3.2	14.6		11.6	3.4
(1978)	E	60		54.0	9.3	4.8	14.4		12.6	4.7
Lloyd	R	46	32.6^{a}	53.8^{a}	4.4	4.1	17.1	12.9	11.7	2.9^{a}
(1980)	W	40	29.0^{b}	56.1^{b}	5.4	4.1	15.7	13.0	11.8	3.3^{b}
Schanbacher	R	10	22.2		4.8^{a}	2.9^{x}			10.0^{x}	1.6^{x}
(1980)	W	10	22.8		6.9^{b}	4.0^{y}			11.2^{y}	1.8^{y}
Crouse	R	78	35.0^{a}		5.9^{x}	2.9^{x}	18.3^{a}	12.3	11.6^{x}	3.3^{x}
(1981)	W	75	36.3^{b}		9.3^{y}	5.0^{y}	17.5^{b}	12.5	12.5^{y}	4.7^{y}
Magid	R	135	27.1^{b}	51.1	4.0^{x}	3.0^{x}		11.4	10.5	3.3^{x}
(1981b)	E	163	24.2^{a}	51.8	6.5^{y}	4.2^{y}		11.2	10.9	4.3^{y}
Hawkins	W	59	21.5	51.2	5.1	2.6^{a}	14.5		12.5	3.0
(1985a)	E	54	21.5	52.0	5.5	3.2^{b}	14.4		12.7	3.2

[1]R=Rams; W=Wethers; E=Ewes
[2]9.0=Good+; 12=Choice+; 13=Prime-
[3]2.0=47.2% retail cuts; 3.0=45.4% retail cuts; 4.0=43.6% retail cuts
[4]was not tested statistically
different superscripts within a column within a study differ a,b,c $P<.05$; x,y,z $P<.01$

in percentage of retail cuts (45% vs 43%) compared to ewes (Shelton and Carpenter, 1972; Adams et al., 1977; Crouse et al., 1978., Herriman et al., 1978; Magid et al., 1981b).

Butler-Hogg et al. (1984) found rams had 7% more lean tissue and 11% more bone than ewes when compared at equal carcass weights. Ewes had 31% and 23% more fat in the subcutaneous and intermuscular depots, respectively, and had twice as much kidney-pelvic fat as rams.

In one of the first studies of growth and development of lambs Hammond, (1932) compared a ram and a wether at a constant age, and found the wether to have a greater development of fat while the ram had a greater development of muscle and bone. Wethers average 48% greater subcutaneous fat depth at the 12th rib than rams (Oliver et al., 1967; Kemp et al., 1970; Glimp, 1971; Shelton and Carpenter, 1972; Lloyd et al., 1980; Schanbacher et al., 1980; Crouse et al., 1981) and average 25% more KP fat (Kemp et al., 1970; Shelton and Carpenter, 1972; Lloyd et al., 1980; Crouse et al., 1981). Dressing percentage of wethers averages 2% higher than dressing percentage of rams (Hunt et al., 1938; Kemp et al., 1970; Glimp, 1971; Shelton and Carpenter, 1972; Lloyd et al., 1980; Schanbacher et al., 1980; Crouse et al., 1981). Rams have a 5% larger ribeye area (Oliver et al., 1967; Shelton and Carpenter, 1972; Lloyd et al., 1980; Crouse et al., 1981) while their legscore is one-third of a grade lower (Lloyd et al., 1980; Crouse et al., 1981). Wether and ram carcasses both

usually attain the USDA choice grade (Shelton and Carpenter, 1972; Lloyd et al., 1980; Schanbacher et al., 1980; Crouse et al., 1981). Yield grade differences indicate a higher cutability for rams compared to wethers and percentage of retail cuts averages 1.3% higher for ram carcasses (Shelton and Carpenter, 1972; Lloyd et al., 1980; Schanbacher et al., 1980; Crouse et al., 1981).

Bradford and Spurlock (1964) compared rams and wethers, finding rams to have an average of 0.5% more of the carcass in each of the four cuts comprising the front half of the carcass than wethers. No differences were found between rams and wethers in percentage of the carcass comprised of the loin and trimmed leg.

Fatness differences between males and females are reduced by castration. Ewes average 17% more subcutaneous fat over the M. longissimus at the 12th rib than wethers (Oliver et al., 1967; Shelton and Carpenter, 1972; Dahmen et al., 1977; Hawkins et al., 1985a) and 36% more kidney-pelvic fat as a proportion of carcass weight (Shelton and Carpenter, 1972; Dahmen et al., 1977; Hawkins et al., 1985a). Ewes average 1% higher dressing percentage (Shelton and Carpenter, 1972; Dahmen et al., 1977; Hawkins et al., 1985a). Muscling differences are slight; wethers averaged a 2% larger ribeye area (Oliver et al., 1967; Shelton and Carpenter, 1972; Dahmen et al., 1977; Hawkins et al., 1985a) with no difference in legscore (Dahmen et

al., 1977). Both ewe and wether carcasses are of high quality, averaging choice plus (Shelton and Carpenter, 1972; Dahmen et al., 1977; Hawkins et al., 1985a). Wethers have less than one-half of a USDA yield grade advantage over ewes, translating to a 0.7% advantage in percentage of retail cuts (Shelton and Carpenter, 1972; Dahmen et al., 1977; Hawkins et al., 1985a).

Overall, ram carcasses are leaner than wethers which are leaner than ewes. Rams have slightly lower legscores and larger ribeye area than either wethers or ewes. Ram carcasses are of higher cutability than either wether or ewe carcasses with a greater proportion of weight in the cuts of the front half and no difference in the loin or trimmed leg. Rams, wethers and ewes are all of acceptable USDA quality.

Examination of carcass composition by proximate analysis has found significant differences between the sexes (Table 4). Everitt and Jury (1966) and Kirton (1982) found rams to have 6% less fat, 1.2% more protein and 4.5% more body water than ewes. Comparison of rams and wethers finds rams to have 3% less fat, 0.6% more protein and 2.4% more body water. Wethers compared to ewes have 3% less fat, 0.6% more protein and 2% more body water (Kirton, 1982). Hawkins et al. (1985a) found wethers to have 2% less fat, 0.5% more protein and 1.5% more body water than did ewes.

Burton and Reid (1969) found that the variation in

Table 4. Summary of Literature Reporting Sex and/or Castration Effects on Lamb Carcass Composition

Reference	Sex	n	%Fat	%Protein	%Body Water
Everitt (1966)	R	5	29.9[a]	15.3[a]	51.0[a]
	E	5	35.8[b]	14.0[b]	46.5[b]
Kirton (1974)	R	78	25.6[a]	14.9[a]	55.9[a]
	W	53	28.8[b]	14.3[b]	53.5[b]
	E	52	31.5[c]	13.7[c]	51.5[c]
Hawkins (1985a)	W	59	26.6[a]	15.7[a]	53.4[a]
	E	54	28.5[b]	15.1[b]	51.9[b]

R=Rams; W=Wethers; E=Ewes
different superscripts within a column within a study differ P<.05

body composition of sheep within the sexes is overwhelmingly accounted for by the variability in body weight and only a small part of the variation is attributable to age differences. Comparison by Hammond (1932) of a ewe with a ram and a wether at five months of age found the ewe to be fattest. This he attributed to the difference between females and males in reaching mature size, the female reaching maturity earlier than the male.

Ewes commence fat deposition at a lighter weight and an earlier age than rams (Jones, 1982). Distribution of fat in the carcass is related to the total amount of fat and is not affected by sex (Thompson et al., 1979). Between wethers and rams, however, there are compositional differences. Discrepancies seen between wethers and rams when compared at an equal weight are not due to maturity (Butterfield et al., 1984). If the fat depots are compared between wethers and rams at an equal weight of total fat or at the same total fat maturity, rams have less subcutaneous and more intermuscular fat. Butterfield et al. (1985) found castration causes a differential partitioning of the quantity of fat to the various depots. The differential partitioning may be the result of hormonal control on adipocyte volume. Castration, through the reduction of androgens, may increase adipocyte volume in the subcutaneous depot and decrease volume in the intermuscular depot. At equal subcutaneous fat depths, rams are fatter than wethers due to the partitioning differences.

Effect of Genotype

Differences between breeds of sheep at an equal weight are attributed to two factors: stage of physiological or growth maturity and breed type. Breeds mature at different rates, and compositional differences are seen at maturity due to breed type. Fat partitioning differs between the meat, wool, milk and prolific breeds because each type places a different demand on the various depots in times of growth (Wood et al., 1980).

Hulet et al. (1984) in an evaluation of Polypay, Targhee, Dorset x Targhee and Finn x Rambouillet for meat type conformation ranked the breeds from best to worst in the following order: Dorset x Targhee, Polypay, Targhee and Finn x Rambouillet. Using a scale of 2-16 all four genotypes fell in the range of 7.45-9.24, thus all the genotypes are only of average carcass merit. Since the Polypay was developed to increase prolificacy of western range ewes, very few carcass studies have been done with this breed. Therefore, for the purpose of this review, the foundation breeds of the Polypay will be compared to the Suffolk (considered the best carcass breed) to give an indication of their carcass quality.

In a comparison of Finnsheep and Suffolks (Table 5), Boylan et al. (1976) found Finns to have 21% less subcutaneous fat depth over the M. longissimus at the 12th rib and 110% more kidney pelvic fat (5.64% vs. 2.68%). Finns had a 23% smaller ribeye area and a 1.3% lower

Table 5. Summary of Literature Reporting the Effect of Lamb Genotype on Carcass Traits

Reference	Breed[1]	n	CCW (Kg)	Dressing %	Fat Depth (mm)	% KP	REA (cm^2)	Leg[2] Score	USDA[2] Quality Grade	USDA[3] Yield Grade
Dickerson (1972)	S	30	31.5	53.2	3.5	2.8	16.5	13.0	12.0	2.6
	D	21	23.6	53.4	3.1	2.7	3.3	13.0	12.0	2.5
	T	98	26.4	50.8	4.4	3.6	12.5	11.0	10.0	3.1
	R	22	25.4	48.9	4.1	2.9	13.0	11.0	10.0	2.9
Kirton (1974)	Rom	39	13.0	39.1[w]	0.9[x]					
	C	39	13.5	42.4[x]	1.9[y]					
	Per	39	17.0	46.7[y]	2.9[z]					
	BL x Rom	39	16.9	45.2[z]	2.8[z]					
Boylan (1976)	S	24	24.2		3.6[x]	2.7[x]	15.0[x]		10.0	2.7[x]
	T	21	22.9		3.9[y]	3.2[y]	13.0[y]		10.0	3.0[y]
	Finn	4	22.8		2.9[z]	5.6[z]	11.5[z]		10.0	3.4[z]
Thomas (1976)	DxRxF	36		49.2	7.0	4.4[x]	14.1	11.7	12.2	
	DxR	24		49.4	7.3	3.7[y]	15.1	11.6	12.5	
Dahmen (1977)	SxPan	28	24.3[y]	49.7[a]	6.2	3.0	14.1[a]	12.5	12.0	3.4[a]
	Sx Pan x F	19	23.0[x]	50.6[b]	7.1	3.6	12.5[b]	12.3	12.0	3.7[b]
Purchas (1978)	SxBLx Rom	23	25.5		9.3	2.8	17.2			

(cont.)

Table 5 (cont.). Summary of Literature Reporting the Effect of Lamb Genotype on Carcass Traits

Reference	Breed[1]	n	CCW (Kg)	Dressing %	Fat Depth (mm)	% KP	REA (cm^2)	Leg[2] Score	USDA[2] Quality Grade	USDA[3] Yield Grade
Lloyd (1980)	BF	45	32.2^{y}	55.5^{b}	5.5^{b}	4.3^{b}	17.0	13.4^{y}	12.2^{y}	3.2
	WF	41	29.4^{x}	54.4^{a}	4.3^{a}	3.9^{a}	15.7	12.5^{x}	11.4^{x}	3.0
Crouse (1981)	SxFx	78	36.1^{y}		7.5	3.6^{x}	18.1	12.7^{x}	12.2^{x}	3.9
	RxFx	75	35.2^{x}		7.6	4.4^{y}	17.1	12.1^{y}	12.0^{y}	4.1
Collins (1982)	P	27		51.4	6.0	2.8	13.0^{a}	11.9^{a}	11.5^{a}	3.3
	D	21		52.5	6.5	2.9	13.9^{ab}	12.5^{b}	12.3^{bc}	3.4
	BL	18		51.5	6.5	2.9	13.9^{ab}	12.2^{ab}	12.4^{b}	3.5
	S	20		51.0	4.6	2.7	15.0^{b}	12.5^{b}	12.1^{c}	2.9
Magid (1981a)	BL	19	25.7	51.8	2.1^{y}	2.6^{x}		9.6	8.7^{y}	2.4
	Finn	51	25.6	51.6	1.5^{x}	3.0^{y}		9.1	7.9	2.4
Magid (1981b)	SxBL	117	20.4	51.7	5.7^{y}	3.3^{x}		11.4	10.9^{y}	3.8
	SxF	181	21.0	51.2	4.7^{x}	3.9^{y}		11.1	10.5^{x}	3.9
Lirette (1984)	S	10	16.7	50.1	6.0	1.0				
	Finn	10	12.5	47.6	3.3	1.9				

[1]S=Suffolk; T=Targhee; F=Finn; Fx=Finn cross; R=Rambouillet; BL=Border Leicester; Rom=Romney; Per=Perendale; C=Corriedale; D=Dorset; Pan=Panama; BF=blackface; WF=whiteface

[2]9=Good+; 12=Choice+; 13=Prime-

[3]2.0=47.2% retail cuts; 3.0=45.4% retail cuts; 4.0=43.6% retail cuts

different superscripts within a column within a study differ a,b,c $P<.05$; x,y,z $P<.01$

cutability as indicated by a higher numerical yield grade. Lirette et al. (1984) found Finns to have 45% less subcutaneous fat at the 12th rib and 86% more KP fat at a mean cold carcass weight 4 kg lighter than the Suffolks. Dressing percentage of the Finns was 2.5% lower.

In a study of the progeny resulting from Suffolk sires and Panama dams versus progeny of Suffolk sires and Panama x Finn dams, Dahmen et al. (1977) found the Finn cross lambs to have a 16% greater subcutaneous fat depth and 22% more KP fat. Dressing percentage for the Finn cross lambs was 1% higher. Finn cross lambs averaged an 11% smaller ribeye area. Both legscore and quality grade showed no difference between genotypes and overall the Finn crosses had a 0.5% lower retail yield. The authors concluded that upon visual appraisal the Finnsheep appears to be inferior to most of our domestic breeds in overall muscling.

Comparison of Suffolk-Finn cross lambs with Rambouillet-Finn cross lambs found the Rambouillet cross lambs to have 20% more KP fat and no difference in subcutaneous fat depth. The Rambouillet cross had 2% less ribeye area, but no appreciable differences in legscore or quality grade. Rambouillet cross carcasses had a higher numerical yield grade predicting a 0.5% lower carcass cutout (Crouse et al., 1981).

Dickerson et al. (1972) compared carcass traits of Suffolks, Dorsets, Targhees and Rambouillets. Dorsets had the least subcutaneous fat depth over the M. longissimus

and lowest proportion of KP fat followed in order for both traits by Suffolks, Rambouillets and Targhees. Dorsets and Suffolks had the highest dressing percentage followed by Targhees and Rambouillets. Suffolks had the biggest ribeye area followed by Dorsets, Rambouillets and Targhees. Legscores and USDA quality grades of Suffolks and Dorsets averaged two-thirds of a grade higher than legscores and quality grades of either Targhees or Rambouillets. Dorsets had only a slightly better retail yield than the Suffolks which, in turn, had a 0.4% and 0.6% advantage in retail yield over the Rambouillets and Targhees respectively. Suffolks had a mean carcass weight which was 5, 6 and 8kg heavier than the carcasses of the Targhee, Rambouillet and Dorset. Had the comparisons been made at an equal carcass weight the advantage of the Dorset over the Suffolk in subcutaneous fat depth, KP fat and yield grade would likely be reversed.

Thomas et al. (1976) in a comparison of genotypes of varied proportions of Dorset and Rambouillet with and without Finn breeding found that the substitution of 25% Finn genes decreased subcutaneous fat depth 4% while increasing kidney pelvic fat by 18%. Ribeye area was reduced 6% by the substitution of the Finn genes, but no difference was seen in legscore or quality grade.

Based on the comparison of the Polypay foundation breeds to the Suffolk, the Polypay should produce a carcass

that has slightly more subcutaneous and KP fat. The Polypay will be only moderately muscled in comparison to the Suffolk with both a smaller ribeye area and a lower legscore. Quality of the Polypay will be slightly lower and yield of retail cuts will be approximately 1% less than the Suffolk.

The Coopworth is often used in terminal crosses in New Zealand. It produces a well muscled carcass with minimal fat under their forage management schemes for the lightweight carcass trade (approximately 15 kg). Very little is known about its carcass quality at heavier weights. From the carcass data for Suffolk x Border Leicester-Romney crosses (comparable to a Suffolk x Coopworth cross) presented in Table 5 it appears to have more subcutaneous fat than the Suffolk, but a similar level of KP fat. Ribeye area is comparable with our domestic breeds (Purchas, 1978). Work by Kirton et al. (1974) found that Border Leicester-Romney crosses produce significantly heavier carcasses at an earlier age than many of the New Zealand breeds while maintaining acceptable fat levels.

Comparison of Border Leicester and Finn sired male progeny found the Finn to have 29% less subcutaneous fat depth, 15% more kidney pelvic fat and no difference in dressing percentage (Magid et al., 1981a). Legscore showed no difference, but was indicative of poor muscling. Neither of the crosses obtained the USDA choice grade and the Finn crosses were one-third of a grade lower than the

Border Leicester crosses. The two crosses had high cutability with no difference in yield grade. Magid et al. (1981b) took the female progeny from the previous experiment and mated them to Suffolk rams to evaluate their offspring for carcass merit. Finn cross lambs had 18% less subcutaneous fat depth at the 12th rib and 18% more KP fat. No difference in dressing percentage was observed. Leg score did not differ and indicated a higher degree of muscling than in the previous trial. Both crosses attained the USDA choice grade. Yield grade indicated no cutability differences between the two crosses.

Collins (1982) evaluated the male sibs of F_1 ewes produced from Polypay, Dorset, Border Leicester and Suffolk sires and Panama dams. Suffolks had the least subcutaneous fat depth, the lowest proportion of KP fat and the lowest dressing percentage of the four crosses, followed in order by, Polypay, Border Leicester and Dorset. Suffolks had the largest ribeye area and the most desirable legscore while Polypays had the smallest ribeye and the least desirable legscore. Quality grades averaged the USDA choice plus grade and were similar for all four crosses. Suffolks had the highest retail yield with a 0.7%, 0.9% and 1.0% advantage over the Polypays, Dorsets and Border Leicesters respectively.

Use of the Coopworth for production of heavy weight market lambs should produce carcasses that are acceptable

by U.S. standards. Coopworth lambs appear to be very similar to Dorset lambs in terms of the carcasses they produce. Like the Dorset, they will produce a carcass which has more subcutaneous fat than a Suffolk, but will be comparably muscled. However, they probably cannot be slaughtered at as heavy a liveweight as the Suffolk. Comparison of the Coopworth to the Polypay will likely find the Polypay to have less subcutaneous fat and more KP fat. The Polypay will be lighter muscled than the Coopworth, but should have a slightly higher retail yield due to less fat.

Comparison of blackface cross lambs and whiteface cross lambs shows the whiteface lambs to have 13% more subcutaneous fat depth at the 12th rib and 18% more KP fat. Whiteface lambs are less heavily muscled as indicated by an 11% smaller ribeye area (Dickerson et al., 1972; Boylan et al., 1976; Crouse et al., 1981) and an average legscore one-third of a grade lower (Dickerson et al., 1972; Crouse et al., 1981). USDA quality grade of whiteface lambs is slightly lower, but both crosses make the choice grade (Dickerson et al., 1972; Boylan et al., 1976; Crouse et al., 1981). Overall the blackface lambs have a 0.7% advantage in cutability as indicated by a lower numerical yield grade (Dickerson et al., 1972; Boylan et al., 1976; Crouse et al., 1981).

As an exception, Lloyd et al. (1980) found blackface lambs to have lower cutability than whiteface lambs largely due to 27% more subcutaneous fat depth and 11% more KP fat.

Blackface lambs had an 8% bigger ribeye area and a legscore which averaged one-third of a grade higher. Since all lambs had a very light subcutaneous fat cover, the difference in fat deposition is probably due to the the blackface lambs being slaughtered at liveweights averaging 4 kg heavier. Heavier lambs, hence heavier carcasses, have been shown to have increased proportions of fat (Kemp et al., 1970).

Effect of Feeding Regimen

Feeding management as well as plane of nutrition has a profound influence on carcass composition, especially fat deposition. Pálsson and Vergés (1952) found that late developing tissues such as fat are restricted by a low plane of nutrition, and the low plane of nutrition will mask potential sex differences. They further found that a high plane of nutrition is essential for good development of the subcutaneous fat depot. This is in agreement with Butler-Hogg and Johnsson (1986) who, in addition, found that when food intake is not restricted, but the composition and energy content of the diet are manipulated to produce differences in growth rate, the faster growing animals will have more fat, especially in the subcutaneous depot. Conversely, Reid et al. (1968) found that a variety of ration compositions of different energy content failed to influence body composition of wethers compared at a constant weight as long as a continuous positive body

energy balance was maintained.

Purchas (1974) found pasture fed lambs to have 15% less subcutaneous fat depth at the 12th rib and 0.6% more KP fat than grain fed lambs slaughtered at the same weight. The 6% greater ribeye area of the pasture lambs was not significantly larger.

Ely et al. (1979) using proximate analysis, found pasture lambs supplemented with concentrate to have approximately 4% less fat and 2% more protein than drylot lambs slaughtered at a constant weight. Dressing percentage of pasture lambs was only 0.5% lower than for drylot lambs. Quality grade was unaffected by the pasture feeding with lambs from both feeding systems averaging the USDA choice grade. Overall pasture fed lambs were leaner and had a higher cutability carcass indicated by a 1.3% advantage in percentage of retail cuts.

MUSCLE FIBER TYPE DIFFERENTIATION

Introduction

Skeletal muscle fibers can be classified into two fundamental fiber types, alpha and beta. Differentiation is on the basis of myosin ATPase activity. Alpha fibers are physiologically fast contracting fibers whereas beta fibers are slow contracting. Muscle fibers can also be classified into red and white fiber types. Red fibers are more mitochondrial dense than are white fibers, representing lower glycolytic enzyme activity. These two

methods of classification can be combined to form three subjectively defined histochemical categories: beta red, alpha red and alpha white (Ashmore et al., 1972). Beta red fibers are slow contracting with an oxidative metabolism, while alpha white fibers are fast contracting with a glycolytic metabolism. Alpha red fibers are intermediate, demonstrating both slow and fast contractile activity and oxidative and glycolytic metabolisms. Ashmore et al. (1972) have postulated that alpha red fibers, are capable of transformation to alpha white fibers and since postnatal increase in muscle size is largely through hypertrophy rather than hyperplasia (Beitz, 1985), the increasing proportions of alpha white fibers are due to this transformation. In less active porcine, ovine and bovine muscles such as the M. longissimus compared to more active muscles, such as the M. semitendinosus there is a greater transformation of alpha red fibers to alpha white fibers. Typical proportions of the beta red, alpha red and alpha white fiber types in the M. longissimus of cattle are, 20%, 25% and 55%, respectively, and for sheep are, 15%, 40% and 45%, though the proportions of alpha red and alpha white fibers are often reversed in sheep. Swine have a higher proportion of alpha white fibers than cattle or lambs. Typical proportions for the M. longissimus of swine are, 14%, 6% and 70% of beta red, alpha red and alpha white fiber types, respectively.

Both selection of individuals for increasing muscularity and management schemes which restrict muscular activity will probably increase lean yield in meat producing animals (Ashmore et al., 1972). Alpha white fibers are the largest in diameter, hence selection for muscularity indirectly selects animals with a high proportion of alpha white fibers. Lack of exercise in confinement management schemes decreases the need for muscles which are comprised of high proportions of fibers having an oxidative metabolism. Selection of individuals easily adapted to confinement management may promote transformation of the alpha red fibers to the alpha white fibers. Selection which increases alpha white fiber proportion may also promote qualitative changes in the meat. For example, muscles that have a high proportion of alpha white fibers have less intramuscular fat or marbling (Ashmore et al., 1972).

Swatland (1976), working with porcine M. longissimus, found that muscle fiber histochemistry appears to be more a continuous variable than a discrete variable. Using cytophotometry together with histochemical staining, he concluded that fibers at the borderlines of the beta red, alpha red and alpha white categories may be fibers in transition.

SUMMARY OF GENETIC AND ENVIRONMENTAL EFFECTS ON MUSCLE FIBER TYPE PROPORTIONS

Muscle fibers in cattle differ between the sexes more in size than in type. The largest difference in type is seen in the proportion of alpha white fibers with heifers having 5 to 6% more than bulls. Bulls have 4% and 2% higher proportions of the alpha red and beta red fiber types respectively (Cornforth et al., 1980; Spindler et al., 1980; Johnston et al., 1981). There is individual muscle variation, but the above generalizations for differences due to sex hold true for most major meat muscles. Cornforth et al. (1980) slaughtered their animals at a constant physiological maturity while Spindler et al. (1980) and Johnston et al. (1981) slaughtered at a constant age. Since the magnitude of the differences in fiber type proportions are approximately the same in these three trials, it does not appear that muscle fiber type proportions of cattle are influenced by physiological maturity differences between the sexes. Spindler et al. (1980) in the course of their research took seven biopsies of the M. biceps femoris of each animal at 56 day intervals from day 28 to slaughter. They found proportions of beta red fibers within a muscle of an individual stayed essentially constant. Proportions of alpha red fibers decreased however, and proportions of alpha white fibers increased during growth with no change in total fiber number. The extent of the transformation and the time of

the transformation differed between genotypes.

Comparison of the red and white fiber types in the M. longissimus between half-sib bulls and steers found proportion of each type to vary by 2%. Steers had more white fibers and fewer red fibers. When the data was adjusted for weaning and slaughter weight there were no differences in fiber types between bulls and steers (Ockerman et al., 1984).

Compared to cattle, mice muscle varies in its proportions of the three fiber types. Mice have a much higher proportion of oxidative fibers which is probably due to a greater metabolic activity. Females have a 3 to 5% higher proportion of beta red fibers in the soleus muscle than castrates which, in turn, have a 10% greater proportion of beta red fibers than intact males (Vaughan et al., 1974). Vaughan et al. also found age had no effect on the proportions of beta red fibers in the soleus muscle.

The potential effects of castration on muscle fiber type proportions are not known, but testosterone is known to stimulate muscular development (Florini, 1985). Spindler et al. (1980) and Ockerman et al. (1984) reported that castration had no effect on fiber type proportions in beef cattle. Castration has been found to not significantly affect the concentration of DNA (mg DNA/g muscle), total protein (mg protein/g muscle), collagen (mg/g muscle), sarcoplasmic proteins (mg/g muscle) or

muscle fiber diameter of the M. longissimus in cattle (LaFlamme et al., 1973). It has been found to increase both the marbling score by a full degree and the percentage of fat in the M. longissimus by one-third over bulls without significantly altering protein levels (Gregory et al., 1983).

Calkins et al. (1981), working with beef cattle, found correlations between marbling score and percentage alpha white fibers, the ratio of beta red to alpha white fibers and the ratio of alpha white to alpha red fibers to be -0.50, 0.46 and -0.43, respectively. They concluded that a greater proportion of oxidative fibers are present when there is a greater amount of marbling.

Vaughan et al. (1974) postulated that fiber types of mice with differential myosin ATPase activities can be modified by androgen levels. They concluded that the change in fiber types was an indirect result of the androgens' influence on the animal's metabolism. Thus it appears that castration might affect different species differently.

Variation of muscle fiber type seen between genotypes is not consistent between muscles. The majority of the variation is in the alpha fibers. Cornforth et al. (1980) found Holsteins at slaughter had a 5% lower proportion of alpha white fibers and a 3% higher proportion of alpha red fibers in the M. biceps femoris when compared to Angus and Herefords. Also in a comparison of the alpha white fibers

in the M. longissimus they found Holsteins to have an 8% lower proportion of alpha white fibers than the Angus and Herefords.

The multiple biopsy technique of Spindler et al. (1980) found differences in muscle fiber type proportions of Holsteins, Angus and Herefords to be approximately the same as Cornforth et al. (1980) until slaughter. At slaughter they observed a significant breed x sex interaction. No differences were observed between breeds for the alpha white fiber type proportions except for Angus heifers which had a significantly lower proportion. The work of both Cornforth et al. (1980) and Spindler et al. (1980) demonstrates that alpha red and alpha white fiber type proportions differ between genotypes. The rate of transformation of alpha red to alpha white may vary due to physiological maturity differences between breeds.

May et al. (1977) found variation of approximately 3 and 4% for the proportions of alpha red and alpha white fibers types, respectively, in the M. longissimus of steers resulting from Simmental, Hereford and Limousin sires mated to Angus dams. When slaughtered at a constant age the Limousin crosses had the highest proportion of the alpha white fibers and lowest proportion of alpha red fibers. This was attributed to their heavier muscling compared to Simmentals and Herefords.

Johnston et al. (1981) conducted two experiments and

found no variation due to genotype in the three fiber types of the M. longissimus when comparing Angus, 3/4 Angus and 1/2 Angus and when comparing Angus and Simmental crosses. In the experiment using Angus and Simmental crosses, examination of the muscles of the round (M. semitendinosus and M. biceps femoris), revealed variation of approximately 5%, 2% and 3% in the beta red, alpha red and alpha white fiber types between the genotypes. Simmental crosses had a higher proportion of alpha white fibers and lower proportions of the alpha red and beta red fiber types. A significant breed x feeding system interaction was found for the proportions of fiber types in the M. longissimus, M. semitendinosus and M. biceps femoris in the second trial. The four feeding regimens had a highly erratic effect on the proportions of beta and alpha red fibers.

Differences in muscle fiber type proportions due to genotype appear to be due to muscling and maturity differences. Genotypes that are more heavily muscled have more white fibers while genotypes that mature later (Holsteins) appear to have a greater proportion of alpha red fibers. Differences in fiber type proportions are likely to be the greatest if the differing genotypes are slaughtered at a constant weight, thereby expressing the differential tissue growth more completely than would comparison at a constant age.

Greater differences are seen in the proportion of muscle fiber types between mouse genotypes than between

cattle genotypes. Albino mice were found to have 12% more beta red fibers than brown mice of equal age (Vaughan et al., 1974).

Muscle fiber research pertaining to total animal growth and body and carcass composition is limited for swine. Much of the muscle fiber work done with swine has focused on the relationship of muscle fiber type to individual muscle growth or explaining the occurrence of PSE in pork.

Staun (1963) found that between the sexes (boars, gilts and barrows) total fiber number for a muscle does not vary by more than 3%. He concluded that muscle size differences were due to different proportions of fiber types and their varying diameters.

Miller et al. (1975) using two lines of Hampshire, a single line of Yorkshire and crosses of the two breeds (total of five genotypes), found beta red and alpha red fiber types to vary by 3 and 2% between the genotypes. Yorkshires had the highest proportion of beta red and alpha red fiber types, while the two lines of Hampshires had the lowest proportions. The crosses were the result of mating Hampshire sires of both lines to Yorkshire females. Crosses had slightly higher proportions of beta red and alpha red fiber types than the Hampshire strains, but significantly less than the Yorkshire genotype. Barrows varied from gilts by less than 1% for all fiber types

(Miller et al., 1975). The authors concluded that red (beta and alpha) fiber proportions and diameters appeared unrelated to either muscle mass or growth rate.

FACTORS AFFECTING MUSCLE FIBER TYPE PROPORTIONS OF LAMBS

Effect of Sex and Castration

No comparisons have been reported on muscle fiber type differences between rams and ewes, but comparisons between wethers and ewes have shown considerable variation (Table 6). Moody et al. (1980) found wethers to have a 2% lower proportion of beta red fibers and a 2% higher proportion of alpha red fibers in the M. longissimus than ewes. In contrast to this, Solomon et al. (1981) found wethers to have approximately a 3% lower proportion of alpha red fibers and a 3% higher proportion of alpha white fibers in the M. longissimus. In the M. semimembranosus wethers had a 5.5% lower proportion of alpha red fibers and a 3.5% higher proportion of alpha white fibers. Hawkins et al. (1985b) found considerable variation in muscle fiber type proportions of different muscles when comparing wethers and ewes. Examination of the M. longissimus found the wethers to have a lower proportion of alpha white fibers while in the M. semimembranosus wethers had a higher proportion of alpha white fibers than the ewes. Moody et al. (1980) found rams to have approximately a 2% higher proportion of both beta red fibers and alpha white than wethers. Proportion of alpha red fibers of the rams was 5% lower.

Effect of Genotype

Using the progeny of two dam genotypes (Suffolk x

Table 6. Summary of Literature Reporting Lamb Muscle Fiber Type Proportions

Reference	Effect	n	Muscle: M. longissimus βR[1]	αR	αW	M. semimembranosus βR	αR	αW
	Sex							
Moody (1980)	Rams	36	11.7^{x}	46.3^{x}	41.9			
	Wethers	36	9.8^{y}	51.0^{y}	39.9			
	Wethers	32	18.4	43.8	39.8			
	Ewes	32	20.5	41.8	39.7			
Solomon (1981)	Wethers	18	6.6	38.4	55.0	15.1	35.9^{a}	46.2
	Ewes	15	6.8	41.2	52.0	16.0	41.4^{b}	42.8
Hawkins (1985b)	Wethers	24	9.3	58.8	31.8	14.7	52.7	32.3
	Ewes	27	8.7	58.2	33.7	14.7	54.6	31.0
	Breed[2]							
Solomon (1981)	SxR	14	7.1	44.5^{b}	48.4^{x}	15.4	43.3^{b}	41.3^{b}
	SxFxSo	19	6.4	37.0^{a}	56.6^{y}	13.1	37.5^{c}	47.3^{a}
Hawkins (1985b)	HxSxR	28	9.2	60.3	30.2	16.3	54.7	29.0
	HxFxSo	23	8.5	58.1	35.3	13.0	54.3	34.0
	Feeding System							
			Experiment 1					
Moody (1980)	Pasture	16	15.8	49.5^{d}	34.6^{d}			
	Drylot	16	17.6	40.2^{e}	42.2^{e}			
			Experiment 2					
	Pasture	24	10.3	53.3d	36.4d			
	Drylot	24	11.6	43.8^{e}	44.7^{e}			

[1] βR=Beta red; αR-Alpha red; αW=Alpha white

[2] S=Suffolk; H=Hampshire; F=Finn; So=Southdown; R=Rambouillet

different superscripts within a column within a study differ a,b P<.10; d,e P<.05; x,y P<.01

Rambouillet considered late maturing and Finn x Southdown considered early maturing) Solomon et al. (1981) found the later maturing genotype to have approximately a 7% higher proportion of alpha red fibers and a 7% lower proportion of alpha white fibers in both the M. longissimus and the M. semimembranosus. Hawkins et al. (1985b), using the same dam genotypes, found similar results with the later maturing genotype having a 2% higher proportion of alpha red fibers and a 5% lower proportion of alpha white fibers in the M. longissimus. The later maturing genotype had a 3% higher proportion of beta red fibers and a 5% lower proportion of alpha white fibers in the M. semimembranosus. The differences seen between genotypes of similar maturities in the two experiments may be due to Solomon et al. using Suffolks sires and Hawkins et al. using Hampshires sires. Hampshires are slightly earlier maturing than Suffolks (Wood et al., 1980).

Effect of Feeding Regimen

Moody et al. (1979) reported two trials conducted to examine the effects of pasture versus drylot finishing on muscle fiber type proportions. In both trials lambs finished on pasture had 9% more alpha red fibers and 9% fewer alpha white fibers. They concluded that the transformation of alpha red fibers to alpha white fibers was enhanced by the higher dietary energy source available to the drylot lambs.

CHAPTER 3

EFFECTS OF SEX, TIME OF CASTRATION, GENOTYPE, AND FEEDING REGIMEN ON LAMB GROWTH AND CARCASS FATNESS

A. M. Arnold and H. H. Meyer

ABSTRACT

Two concurrent trials were conducted to examine the effects of sex, time of castration, genotype, and feeding regimen on lamb growth rate and carcass fatness. Trial 1 compared Polypay and Coopworth x Polypay male lambs either left intact or castrated early, mid or late in growth. Trial 2 compared Hampshire-sired lambs (females, early castrate wethers and late castrate wethers) from Suffolk x Coopworth dams and whiteface x Coopworth dams. Sex and time of castration significantly affected growth rate in Trial 1 but not in Trial 2. Feed efficiency was not affected by sex or time of castration in either trial. Rams were leaner than wethers ($P<.001$) which were leaner than ewe lambs ($P<.001$) when all were slaughtered at a common weight of 52 kg. Delaying castration reduced carcass fatness ($P<.01$). Substitution of Polypay genes with Coopworth genes in crossbred lambs did not significantly alter any of the fatness traits measured. Lambs grazed on irrigated pastures until 41 kg then finished in drylot were leaner and had a lower dressing percentage than lambs fed in the drylot throughout, but USDA quality grades were similar.

INTRODUCTION

The use of ram lambs has long been advocated as a means by which to reduce lamb carcass fatness (Robertson, 1966; Turton, 1969). Work by Butterfield et al. (1984) has shown that when slaughtered at equal weights wethers produce a fatter carcass than rams. Producers have been reluctant to utilize ram lambs because of potential behavioral problems in pubertal ram lambs reaching sexual maturity and the economic penalty imposed on ram lambs at slaughter. Many of the behavioral problems can be avoided by using genotypes that reach slaughter weight before sexual maturity. The slaughter penalty is imposed due to purported lower quality grades, decreased palatability and less desirable carcass weight distribution of ram carcasses. However, studies have shown ram lamb carcasses to be commercially acceptable (Crouse et al., 1978; Magid et al., 1981b) and Bradford and Spurlock (1964) found rams to have a higher yield of lean cuts than wethers.

Delaying castration until the animal has reached a greater proportion of his slaughter weight may allow producers to realize the superior growth and carcass characteristics of ram lambs. Any effects of late castration on carcass growth in lambs has not been reported previously.

The purpose of this study was to examine the effects of delayed castration on growth rate and reduction of

carcass fatness compared to the influences of sex, genotype and feeding regimen.

MATERIAL AND METHODS

Two concurrent trials were conducted utilizing a total of 140 lambs. Trial 1 was comprised of 40 Polypay and 40 Coopworth x Polypay male lambs all born to contemporary Polypay dams. The Coopworth cross lambs were sired by rams imported from New Zealand where the breed has been developed from a Border Leicester x Romney base. Lambs were randomly allocated to treatment groups as shown in table 7. Castration was performed early (within two weeks of birth), mid (weaning, mean weight of 23 kg) and late (upon reaching 39 kg) in growth. All castration was done by surgical removal of the testes.

The sixty Hampshire-sired lambs in Trial 2 lambs (table 7) were born to either Suffolk x Coopworth or whiteface x Coopworth dams and consisted of ewes, early castrates and late castrates. A low ram ratio among Suffolk x Coopworth progeny required proportionately more male lambs from the whiteface x Coopworth dams.

Lambs were run with their dams on ryegrass and white clover pastures until weaning. At weaning, trial lambs were chosen from their larger respective populations so as to minimize variation in both age and starting weight. Trial 1 lambs represented approximately 40% of the available males in their population and Trial 2 lambs

Table 7. Experimental Design

Trial 1

Feeding Regimen	Drylot		Pasture & Drylot	
Breed	Polypay	Coopworth x Polypay	Polypay	Coopworth x Polypay
Sex / Castration				
Wether-early	5	5	5	5
Wether-mid	5	5	5	5
Wether-late	5	5	5	5
Ram	5	5	5	5

Trial 2

Feeding Regimen	Drylot		Pasture & Drylot	
Breed	3/4 BF	1/2 WF	3/4 BF	1/2 WF
Sex / Castration				
Ewes	5	5	5	5
Wether-early	3	7	3	7
Wether-late	3	7	3	7

represented approximately 33% of the available females and 67% of the available males. Lambs were randomly assigned to either drylot where they were fed a pelleted 70% concentrate, 14% crude protein ration until slaughter or they remained on irrigated pastures until reaching 41 kg before transfer to the drylot feeding regimen. All lambs were given a four week postweaning adaptation period to adjust to their environments prior to the start of the trial.

Drylot lambs were grouped within trial by sex/castration treatment and fed ad libitum. Feed was weighed back weekly to calculate pen intake and feed efficiency. Pasture lambs from the two trials were run as a single management group and rotationally grazed over ten 1.5 ha paddocks. Lambs were slaughtered weekly upon reaching 52 kg liveweight.

Lambs were fasted for 24 hours prior to slaughter but had continued access to water. Slaughter was accomplished by commercial procedure at the campus research abattoir. Within one hour post-exsanguination, a 1 cm x 2 cm muscle sample was removed from the right M. longissimus for histological examination as reported by Arnold and Meyer (1987b). Carcasses were USDA quality graded and yield graded after a 48 hour chill. Carcasses were ribbed between the 12th and 13th ribs, allowing determination of ribeye area from a tracing of the left M. longissimus and estimation of subcutaneous fatness as an average of fat

depth over the left and right M. longissimus. Kidney pelvic fat was weighed and calculated as a percentage of cold carcass weight.

Data were analyzed separately for the two trials. Feed efficiency data was analyzed by the analysis of variance procedure of the Statistical Analysis System of the SAS Institute Inc. (1985) fitting castration and feeding period as fixed effects. Main effects were tested against the interaction term.

Growth and carcass parameters were analyzed by the analysis of covariance procedure of the Statistical Analysis System (SAS Institute Inc., 1985), fitting castration, breed and feeding regimen as main effects and slaughter age or initial weight as the covariate. All interactions were included in the model. Plotting the residuals of the dependent variables against the residuals of the covariate (Snedecor and Cochran, 1980) indicated no departure from linearity. Accordingly, the residual error term was used to test significance in all analyses. Single degree of freedom orthogonal comparisons were used to compare the castration treatments within each trial (Steel and Torrie, 1980). For Trial 1, rams were compared to wethers, the early castrates were compared to the later castrates and the mid castrates were compared to the late castrates. For Trial 2, ewes were compared to wethers and the two castration treatments were compared.

RESULTS AND DISCUSSION

Growth rate. Sex exhibited a variable effect on growth between trials. Rams in Trial 1 (Table 8) had higher gains than wethers ($P<.01$), but wethers in Trial 2 (Table 8) did not differ from ewes. Carcass weight per day of age (CW/DA) gives a better indication of carcass growth than does ADG. Differences in CW/DA between rams and wethers in Trial 1 were not significant, however the trend observed agrees with the work of Kemp et al. (1970) who found rams to have a significantly greater CW/DA than wethers. No difference in CW/DA was seen between wethers and ewes in Trial 2. Lack of a sex effect differs from the work of Hawkins et al. (1985a) who found wethers to have a significantly higher CW/DA than ewes in a trial with Hampshire-sired lambs that gained at a faster rate than animals in this trial.

Delaying castration produced an inconsistent effect on ADG. Early castrates in Trial 1 gained significantly slower than an average of the later castrates ($P<.01$), but no difference in ADG was seen between early and late castrates for the faster growing Hampshire cross lambs in Trial 2. Castration time effects on ADG in Trial 1 produced a much smaller effect on carcass weight gains. Dressing percentage and hence carcass weights decreased as castration time was delayed. This was probably due to greater proportionate growth of non-carcass, parts

Table 8. Adjusted Least Squares Means and Standard Errors for Growth Rate and Feed Efficiency

Effect	n	ADG (g)	CW/DA (g)	Feed Efficiency gain (g)/Kg feed
		Trial 1		
Sex / Castration				
Wether-early	19	192 ± 10	102 ± 2	123 ± 8
Wether-mid	20	215 ± 9	105 ± 2	127 ± 8
Wether-late	18	232 ± 10	105 ± 2	134 ± 8
Ram	18	250 ± 10	106 ± 2	146 ± 8
Breed				
Polypay	38	229 ± 7	105 ± 1	
Coopworth	37	216 ± 7	103 ± 1	
Feeding Regimen				
Drylot	37	252 ± 7[c]	112 ± 1[c]	
Pasture & Drylot	38	192 ± 7[d]	97 ± 1[d]	
		Trial 2		
Sex / Castration				
Ewe	20	245 ± 12	116 ± 2	146 ± 7
Wether-early	19	250 ± 14	114 ± 2	138 ± 7
Wether-late	19	252 ± 14	116 ± 2	134 ± 7
Breed				
3/4 BF	22	249 ± 12	117 ± 2	
1/2 BF	36	249 ± 9	114 ± 2	
Feeding Regimen				
Drylot	30	294 ± 11[c]	126 ± 2[c]	
Pasture & Drylot	38	204 ± 11[d]	105 ± 2[d]	

a,b P<.05; c,d P<.01

particularly the head, during the time animals remained intact (Butterfield et al., 1984). No difference in CW/DA due to delayed castration was seen in Trial 2. The faster growth rate of Trial 2 lambs may have reduced the disproportionate growth of non-carcass parts seen between intact males and castrates.

Within each trial genotypic differences did not significantly affect growth rate. This was true for both time lambs spent on pasture, as well as in drylot. Growth rate was not affected by genotype for both feeding periods, from start of the experiment to 41 kg, and 41 to 52 kg. Polypay lambs had a slightly higher ADG than Polypay lambs in Trial 1, and no differences were observed between genotypes in Trial 2. Overall the growth of the Hampshire sired lambs of Trial 2 exceeded that of their whiteface contemporaries in Trial 1. This agrees with the results of Lloyd et al. (1980) and Crouse et al. (1981). Carcass weight/day of age was not affected by breed in either trial.

Feeding regimen exerted the most significant influence on ADG in this experiment. In both trials, lambs fed continuously in drylot had a higher overall ADG ($P<.01$) than lambs finished in drylot following a pasture feeding period. During the period from initiation of the experiment to 41 kg, lambs fed in drylot significantly outgained lambs on pasture ($P<.001$). Following their move to drylot, pastured lambs showed modest compensatory growth

averaging approximately 10% higher daily gains than the drylot lambs over the 41-52 kg range. This difference was not significant. Carcass weight/day of age also differed between feeding regimens in both trials (P<.01). Lambs fed continuously in drylot lambs produced more CW/DA.

Feed Efficiency. The pattern of castration time on ADG was paralleled by increased feed efficiency with increasingly delayed castration. Rams gained approximately 14% more weight per kilogram feed than did wethers (P<.10). This is in agreement with work by Prescott (1969) and Shelton and Carpenter (1972). Delaying castration reduced the difference between rams and wethers. Rams were 19% more efficient than early castrates and only 9% more efficient than late castrates. As with ADG, no significant sex or castration effects were seen for feed efficiency in Trial 2. Comparison of feed efficiencies between the two trials shows blackface lambs to be approximately 5% more efficient than whiteface lambs.

Carcass traits. Sex and time of castration had a significant effect on carcass fatness in both trials. Rams had less subcutaneous fat over the M. longissimus (P<.001) and less kidney-pelvic fat (KP) (P<.001) than did wethers (table 9). Consequently, rams had a lower yield grade than wethers (P<.001) indicating a higher percentage of lean retail cuts. Ewes had more subcutaneous fat over the M. longissimus (P<.001), more KP fat (P<.001) and a higher

Table 9. Adjusted Least Squares Means and Standard Errors for Carcass Traits (Trial 1)

Effect	n	CCW(Kg)	Dressing %	Fat (mm) Depth	%KP	REA(cm^2)	Leg[1] Score	USDA[1] Quality Grade	USDA[2] Yield Grade
Sex / Castration									
Wether-early	19	26.9 ± .3	53.23 ± .54	8.5 ± .6	4.52 ± .23	17.58 ± .41	11.6 ± .3	11.8 ± .2	4.45 ± .19
Wether-mid	20	26.6 ± .2	52.38 ± .48	7.2 ± .5	4.34 ± .20	17.94 ± .36	11.6 ± .2	11.7 ± .2	4.06 ± .17
Wether-late	18	26.4 ± .3	51.39 ± .51	5.1 ± .6	3.59 ± .21	17.36 ± .39	11.7 ± .2	11.6 ± .2	3.32 ± .18
Ram	18	26.0 ± .3	49.94 ± .56	3.7 ± .6	3.17 ± .23	18.16 ± .43	10.8 ± .3	11.2 ± .2	2.90 ± .19
Orthogonal Comparisons									
Rams vs Wethers		P<.05	P<.001	P<.001	P<.001	ns	P<.01	P<.05	P<.001
early vs mid & late		ns	P<.05	P<.01	P<.05	ns	ns	ns	P<.01
mid vs late		ns	ns	P<.01	P<.05	ns	ns	ns	P<.01
Breed									
Polypay	38	26.4 ± .2	51.65 ± .35	5.7 ± .4[x]	3.99 ± .15	17.06 ± .27[e]	11.4 ± .2	11.6 ± .1	3.58 ± .12
Coopworth	37	26.6 ± .2	51.81 ± .36	6.6 ± .4[y]	3.83 ± .15	18.46 ± .27[f]	11.4 ± .2	11.5 ± .1	3.78 ± .12
Feeding Regimen									
Drylot	37	26.8 ± .2[a]	52.36 ± .42[x]	7.0 ± .5[a]	4.20 ± .18[a]	17.70 ± .32	11.4 ± .2	11.6 ± .2	3.97 ± .15[c]
Pasture & Drylot	38	26.1 ± .2[b]	51.11 ± .41[y]	5.3 ± .5[b]	3.61 ± .17[b]	17.82 ± .31	11.4 ± .2	11.5 ± .2	3.39 ± .14[d]

[1]9=Good+; 10=Choice-; 12=Choice+; 13=Prime-
[2]2.0=47.2% retail cuts; 3.0=45.4% retail cuts; 4.0=43.6% retail cuts
a,b P<.05; c,d P<.01; e,f P<.001; x,y P<.10

Table 10. Adjusted Least Squares Means and Standard Errors for Carcass Traits (Trial 2)

Effect	n	CCW(Kg)	Dressing %	Fat (mm) Depth	%KP	REA(cm^2)	Leg[1] Score	USDA[1] Quality Grade	USDA[2] Yield Grade
Sex / Castration									
Ewe	20	27.3 ± .3	53.92 ± .35	7.6 ± .5	4.29 ± .19	18.78 ± .48	12.4 ± .2	11.8 ± .2	4.10 ± .13
Wether-early	19	27.3±0.3	53.02 ± .38	6.7 ± .5	3.49 ± .21	19.59 ± .53	12.2 ± .3	11.7 ± .2	3.68 ± .14
Wether-late	18	27.3 ± .3	53.20 ± .38	3.9 ± .5	3.08 ± .21	19.56 ± .53	12.6 ± .3	11.9 ± .2	2.82 ± .17
Orthogonal Comparisons									
Ewes vs Wethers		ns	P<.01	P<.001	P<.001	ns	ns	ns	P<.001
early vs late		ns	ns	P<.001	ns	ns	ns	ns	P<.001
Breed									
3/4 BF	22	27.3 ± .3	53.24 ± .35	6.1 ± .5	3.42 ± .19[x]	19.74 ± .48	12.5 ± .2	11.8 ± .2	3.49 ± .13
1/2 BF	36	27.3 ± .2	53.52 ± .26	6.0 ± .4	3.82 ± .14[y]	18.89 ± .36	12.2 ± .2	11.8 ± .1	3.57 ± .10
Feeding Regimen									
Drylot	30	27.9 ± ..3[d]	54.59 ± .35[e]	6.0 ± .5	3.97 ± .19[a]	19.67 ± .49	12.5 ± .2	11.8 ± .2	3.59 ± .13
Pasture & Drylot	28	26.7 ± .3[c]	52.18 ± .35[f]	6.1 ± .5	3.28 ± .19[b]	18.94 ± .48	12.2 ± .2	11.8 ± .2	3.47 ± .13

[1]9=Good+; 10=Choice-; 12=Choice+; 13=Prime-
[2]2.0=47.2% retail cuts; 3.0=45.4% retail cuts; 4.0=43.6% retail cuts
a,b P<.05; c,d P<.01; e,f P<.001; x,y P<.10

yield grade (P<.001) than wethers (table 10). Delaying castration resulted in less subcutaneous fat over the M. longissimus (P<.01) in both trials. Late castration also reduced KP by 21% (P<.05) compared to early castration in Trial 1 and by 12% (P=.17) in Trial 2. Yield grades clearly reflect the effect of castration time on carcass fatness in both trials. Similar reduction in the fat indices have been seen with beef cattle castrated at heavier weights (Gregory and Ford, 1983; Worrell et al.,1987).

Both sex and time of castration demonstrated a limited effect on muscling indices. Differences in ribeye area between the two trials indicate a tendency for rams to have a larger ribeye area than wethers which have a larger ribeye area than ewes. Time of castration exerted no effect on ribeye area in either trial. Comparison between the blackface lambs in Trial 2 and whiteface lambs in Trial 1, finds blackface lambs to have a larger ribeye area. Rams have a slightly lower (0.8 units, P<.01) legscore than an average of the wethers in Trial 1. However no difference in legscore was seen between the castration treatments in Trial 1. Blackface lambs in Trial 2 showed no effect of sex or castration time on legscore. Blackface lambs have a higher legscore than whiteface lambs indicative of their superior muscling.

Sex, but not time of castration affected USDA quality grade. Rams had a slightly lower (0.5 units, P<.05)

quality grade than an average of the wethers in Trial 1 but were still in the choice grade. This is in agreement with other carcass studies which have found rams to grade choice (Kemp et al., 1970; Crouse et al., 1981). Time of castration in Trial 1 did not affect USDA quality grade. No differences were seen for quality grade due to either sex or castration time in Trial 2.

Within trials, breed differences had much less effect than either sex or time of castration on carcass traits. Polypays, in Trial 1, showed a tendency toward less subcutaneous fat over the M. longissimus ($P<.10$), and more KP fat than the Coopworths. This was probably a result of the Finn contribution to the Polypay genotype since substitution of Finn genes has been shown to decrease subcutaneous fat depth while increasing KP fat (Thomas et al., 1976). Coopworths had a larger ribeye than the Polypays ($P<.001$). Ribeye area was affected by time of castration, as shown by ribeye area of the Coopworths which was 2% larger than Polypays at the early castration and increased to 20% superiority in ram lambs. The resulting interaction was significant ($P<.05$). The larger ribeye area is likely the result of the Coopworth breed being developed from crosses of breeds that produce more heavily muscled carcasses than the breeds used in development of the Polypay. No differences in carcass traits were seen between the genotypes in Trial 2, as lambs differed by only

25% in breed composition.

Pasture feeding, prior to drylot finishing, significantly reduced carcass fatness without affecting quality. Pasture fed lambs in Trial 1 had less fat over the M. longissimus ($P<.05$), less KP fat ($P<.05$) and consequently lower yield grades ($P<.01$). They also had a lower dressing percentage ($P<.10$), resulting in lighter carcasses ($P<.05$). Pasture feeding did not significantly alter ribeye area, legscore or USDA quality grade. Similar results were obtained by Ely et al. (1979) in a comparison of drylot lambs and pasture lambs supplemented with concentrates. Pasture feeding had a similar effect on KP fat, dressing percentage and carcass weight in Trial 2. However, backfat thickness was not reduced by pasture feeding in these lambs while muscling declines were seen in both ribeye area and legscore. As in Trial 1, USDA quality grade was not affected by the pasture feeding period.

Castration x feeding regimen interaction for KP fat was found to be significant in Trial 1 ($P<.05$). Late castrates in the drylot were found to have less KP fat than late castrates that had a pasture feeding period, which was the opposite result compared to the other castration times. Late castrates may have shown a synergistic effect of decreased testosterone levels and increased protein to energy ratio since both castration and the switch to drylot occurred within approximately 2 kg of liveweight growth. It has been shown (Butler-Hogg and Johnsson, 1986) that the

major effect of changing growth rate over a relatively short period of time is in the distribution of body fat between depots.

Conclusion

Both delaying castration and pasture feeding reduced fatness and increased yields of lamb carcasses when slaughtered occurred at a fixed weight. The apparent advantage of delayed castration on ADG was not totally realized in CW/DA, but delayed castration did increase efficiency of feed utilization. The leaner pasture fed lambs were equal in carcass quality, however, they grew at a slower rate than their drylot contemporaries. A part of the slower growth was compensated upon introduction to drylot for the finishing period.

Hampshire sired lambs grew faster than whiteface lamb, particularly in drylot. They had a higher dressing percentage without increased fatness, the dressing advantage being due to greater muscling in both ribeye area and legscore.

CHAPTER 4

INFLUENCES OF SEX, TIME OF CASTRATION, GENOTYPE, BIRTHTYPE, AND FEEDING REGIMEN ON LAMB MUSCLE FIBER TYPE PROPORTIONS

A. M. Arnold and H. H. Meyer

ABSTRACT

Two trials examined the genetic and environmental influences on muscle fiber type proportions. Trial 1 compared Polypay and Coopworth x Polypay male lambs either left intact or castrated early, mid or late in growth. Trial 2 compared Hampshire-sired lambs (females, early castrate wethers and late castrate wethers) from Suffolk x Coopworth dams and whiteface x Coopworth dams. Half the lambs in each trial were raised from weaning to the standard 52 kg slaughter weight in drylot while the other half were raised to 41 kg on pasture before finishing in drylot. Analysis of M. longissimus tissue samples revealed no significant differences among rams, wethers and ewes in their proportions of muscle fiber types. Early castration increased the proportion of alpha red fibers in Trial 1 ($P<.01$) but not in Trial 2. Polypay lambs had a higher proportion of beta red fibers ($P<.05$) than the Coopworth x Polypay lambs, but no differences were seen between the genotypes in Trial 2. Single-born lambs in Trial 1 had a 6% higher proportion of alpha white fibers ($P<.05$) than twin-born lambs, however, this difference was not seen in Trial 2. Drylot lambs had a higher proportion of beta red

fibers than pasture reared lambs, the difference being 5% ($P<.01$) in Trial 2. Muscle fiber proportions were not found to be related to the induced differences in growth and carcass fatness, and no evidence of differential fiber transformation was found in this trial.

INTRODUCTION

Muscle fiber type proportions change during the growth period (Cornforth et al., 1980). Animals are born with predominantly beta red and alpha red fiber types, and as growth progresses, an increase is seen in the proportions of alpha white fiber types. Since alpha red fibers have the capacity to become alpha white fibers and since postnatal increase in muscle size is largely through hypertrophy, rather than hyperplasia (Beitz, 1985), Ashmore et al. (1972) postulated that the increase in proportion of alpha white fibers is the result of transformation of alpha red fibers to alpha white fibers.

Previous research with lambs (Moody et al., 1980) and with cattle (Johnston et al., 1981) has shown that proportions of the three fiber types differ between sexes, and are affected by the feeding regimen.

Genotype has also been shown to significantly affect muscle fiber proportions of lambs (Solomon et al., 1981), swine (Miller et al., 1975) and cattle (May et al., 1977).

The effects of other factors such as birthtype and

varying time of castration on muscle fiber proportions have not been reported for any species, and few studies with lambs have examined genotypic variation in conjunction with the above factors.

MATERIAL AND METHODS

Two concurrent trials were conducted using a total of 140 lambs. Trial 1 consisted of 40 Polypay and 40 Coopworth x Polypay male lambs. The Coopworth sires had been imported from New Zealand where the breed was developed from a Border Leicester x Romney base. Lambs were randomly assigned within genotype to one of four castration treatments: early (within two weeks of birth), mid (weaning, mean weight of 23 kg), late (upon reaching 39 kg) or none (left intact).

Trial 2 consisted of sixty (40 male, 20 female) Hampshire-sired lambs born to either Suffolk x Coopworth or whiteface x Coopworth dams. Male lambs were randomly assigned either early or late castration.

At weaning, trial lambs were chosen from their larger respective populations so as to minimize variation in age and weight. Trial 1 lambs represented approximately 40% of the available males in their population and Trial 2 lambs represented 33% of the available females and 67% of the available males. Lambs were randomly allotted within treatment subclass to either immediate drylot management or to pasture management until reaching 41 kg and then

drylotted until slaughter at 52 kg. A more detailed description of the castration treatments, genotypes, feeding regimens and lamb management can be found in Arnold and Meyer (1987a).

Within one hour post exsanguination, a 1 cm x 2 cm muscle sample was taken from the medial portion of the M. longissimus between the 12th and 13th ribs. Each sample was immediately placed in a sealed plastic cryostat tubule, and immersed in liquid nitrogen for storage until staining. Samples were removed from the liquid nitrogen and mounted on a cryostat chuck with the fibers perpendicular to the microtome blade. Samples were allowed to equilibrate to -20 C then sectioned at 12μ thickness using an IEC Microtome Cryostat. The sections were mounted on glass microscope slides, air dried, stained for SDH activity and acid stable myosin ATPase using the technique of Solomon and Dunn (1987) and a cover slip was placed over the sections with glycerol gel. Approximately 25% of the samples were found unsuitable for fiber determinations. Sample loss was unrelated to castration treatment, genotype or feeding regimen.

Fibers were counted at 100x with the aid of a 1 mm^2 ocular grid on a Leitz diavert microscope. The grid was positioned randomly over the section since prior analysis had shown no significant differences between fiber type proportions determined within a bundle, compared to

counting of 500 or more fibers irrespective of bundle boundaries. Fiber types were classified according to Ashmore et al. (1972) as beta red, alpha red and alpha white. Proportions of each fiber type were calculated by dividing the number of each type by the total number of fibers counted.

Data for each trial was analyzed separately using the analysis of covariance procedure of the Statistical Analysis System (SAS Institute, 1985). Castration treatment, genotype, feeding regimen and birthtype (single vs. twin) were fitted as main effects with weaning weight as a covariate. All two-way interactions were included in the model. Plotting the residuals of the dependent variables against the residuals of the covariate (Snedecor and Cochran, 1980) indicated no departure from linearity. Accordingly, the residual error term was used in all tests of significance. Single degree of freedom orthogonal comparisons (Steel and Torrie, 1980) were used to compare castration treatment means. For Trial 1, rams were compared to wethers, early castrates were compared to later castrates and mid castrates were compared to late castrates. For Trial 2, ewes were compared to wethers and the two castration treatments were compared.

RESULTS AND DISCUSSION

The effects of sex, castration time, genotype, birthtype and feeding regimen on slaughter age, muscle

parameters and yield grade are shown in tables 11 (Trial 1) and 12 (Trial 2). Muscle fibers/mm^2 was not affected by any of the factors mentioned above, nor was it significantly correlated to any of the traits measured.

Lamb sex did not significantly affect the proportions of the different muscle fiber types in these trials. Rams had slightly more beta and alpha red fibers, and slightly less alpha white fibers compared to an average of the wethers (Trial 1), but proportions of the three muscle fiber types differed by less than 1% between the sex groups. The comparison of rams to early castrate found rams to have a 2% higher proportion of beta red fibers and a 5% lower proportion of alpha red fibers. These results agree with those reported by Moody et al. (1980) in their comparison of rams and early castrated wethers. Comparison of wethers to ewes (Trial 2) found differences in the proportions of muscle fiber types to be larger than those seen between rams and wethers. Ewes had approximately a 1.5% higher proportion of both beta red and alpha white fiber types, and a 3% lower proportion of alpha red fibers than wethers. Comparison of rams from Trial 1 and ewes from Trial 2 showed ewes had a slightly higher proportion of both beta red and alpha white fibers, and a 1% lower proportion of alpha red fibers.

The effect of castration time on muscle fiber type proportions appears to be related to genotype. In Trial 1,

Table 11. Adjusted Least Squares Means and Standard Errors for Slaughter Age, Muscle Fiber Parameters, and Yield Grade (Trial 1)

Effect	n	Slaughter Age (days)	Fibers/ mm^2	% βR^1	% αR^1	% αW^1	αR: αW	USDA[2] Yield Grade
Sex / Castration								
Wether-early	17	285 ± 8	380.9 ± 12.8	8.38 ± 1.31	51.75 ± 2.22	39.87 ± 1.64	1.34 ± .10	4.58 ± .28
Wether-mid	15	270 ± 9	395.7 ± 14.8	10.83 ± 1.28	45.85 ± 2.55	43.31 ± 1.89	1.11 ± .12	4.17 ± .28
Wether-late	13	255 ± 8	375.8 ± 14.5	11.04 ± 1.25	41.28 ± 2.51	47.68 ± 1.86	0.87 ± .11	3.47 ± .27
Ram	11	250 ± 8	391.8 ± 14.5	10.55 ± 1.31	46.80 ± 2.62	42.64 ± 1.94	1.13 ± .12	2.84 ± .24
Orthogonal Comparisons								
Rams vs Wethers		P<.05	ns	ns	ns	ns	ns	P<.001
early vs mid & late		P<.05	ns	P<.10	P<.01	P<.01	P<.05	P<.05
mid vs late		ns	ns	ns	ns	P<.10	ns	P<.10
Breed								
Polypay	28	259 ± 6	394.9 ± 10.6	11.43 ± .91[a]	44.94 ± 1.83	43.63 ± 1.35	1.08 ± .08	3.58 ± .12
Coopworth	28	271 ± 6	377.3 ± 9.8	8.97 ± .85[b]	47.91 ± 1.71	43.12 ± 1.26	1.15 ± .08	3.78 ± .12
Birthtype								
Singles	19	282 ± 9[c]	380.1 ± 15.3	10.09 ± 1.32	43.21 ± 2.64[x]	46.70 ± 1.95[a]	0.92 ± .12[a]	3.90 ± .23
Twins	37	248 ± 6[d]	392.1 ± 9.7	10.31 ± .84	49.64 ± 1.68[y]	40.05 ± 1.25[b]	1.31 ± .08[b]	3.55 ± .14
Feeding Regimen								
Drylot	26	240 ± 6[e]	378.7 ± 10.9	10.28 ± .94	45.76 ± 1.88	43.96 ± 1.40	1.07 ± .08	3.97 ± .15
Pasture & Drylot	30	291 ± 6[f]	393.4 ± 9.88	10.12 ± .84	47.09 ± 1.69	42.79 ± 1.25	1.15 ± .08	3.39 ± .14

[1] βR=Beta red; αR=Alpha red; αW=Alpha white
[2] 2.0=47.2% retail cuts; 3.0=45.4% retail cuts; 4.0=43.6% retail cuts
a,b P<.05; c,d P<.01; e,f P<.001; x,y P<.10

Table 12. Adjusted Least Squares Means and Standard Errors for Slaughter Age, Muscle Fiber Parameters, and Yield Grade (Trial 2)

Effect	n	Slaughter Age (days)	Fibers/ mm^2	%βR[1]	%αR[1]	%αW[1]	αR: αW	USDA[2] Yield Grade
Sex / Castration								
Ewe	13	253 ± 8	378.4 ± 13.9	11.06 ± 1.41	45.73 ± 2.51	43.21 ± 1.97	1.09 ± .11	4.37 ± .21
Wether-early	16	246 ± 6	400.4 ± 11.1	9.55 ± 1.13	47.72 ± 2.01	42.74 ± 1.58	1.16 ± .09	3.61 ± .17
Wether-late	14	254 ± 7	399.1 ± 13.5	9.57 ± 1.37	49.20 ± 2.44	41.23 ± 1.92	1.21 ± .11	2.68 ± .21
Orthogonal Comparisons								
Rams vs Wethers		ns	ns	ns	ns	ns	ns	P<.001
early vs late		ns	ns	ns	ns	ns	ns	P<.001
Breed								
3/4 BF	12	252 ± 7	392.7 ± 12.9	9.92 ± 1.31	48.68 ± 2.34	41.39 ± 1.84	1.20 ± .10	3.49 ± .13
1/2 BF	31	251 ± 4	392.5 ± 7.6	10.19 ± .77	46.42 ± 1.37	43.49 ± 1.08	1.10 ± .06	3.57 ± .10
Birthtype								
Singles	14	254 ± 7	386.8 ± 13.1	10.16 ± 1.33	48.95 ± 2.38	40.88 ± 1.87	1.24 ± .11	3.57 ± .14
Twins	29	248 ± 5	398.5 ± 8.7	9.95 ± .88	46.15 ± 1.57	43.90 ± 1.23	1.07 ± .07	3.52 ± .12
Feeding Regimen								
Drylot	24	225 ± 6^{c}	399.6 ± 10.3	12.47 ± 1.04^{d}	44.96 ± 1.86^{x}	42.57 ± 1.46	1.08 ± .08	3.59 ± .13
Pasture & Drylot	19	278 ± 6^{d}	385.6 ± 10.9	7.65 ± 1.10^{c}	50.14 ± 1.97^{y}	42.21 ± 1.54	1.23 ± .09	3.47 ± .13

[1]βR=Beta red; αR=Alpha red; αW=Alpha white
[2]2.0=47.2% retail cuts; 3.0=45.4% retail cuts; 4.0=43.6% retail cuts
a,b P<.05; c,d P<.01; e,f P<.001; x,y P<.10

early castrates demonstrated a tendency toward a lower proportion of beta red fibers when compared to the later castrates ($P<.10$). Early castrates had an 8% higher proportion of alpha red fibers ($P<.01$) and a 6% lower proportion of alpha white fibers than the later castrates ($P<.01$). No differences were seen between mid and late castrates for either proportion of beta red fibers or proportion of alpha red fibers. Late castrates had a 4% higher proportion of alpha white fibers than the mid castrates ($P<.10$). Time of castration in Trial 2 produced no significant differences. Comparison of the alpha red to alpha white ratio between castration treatments showed slight differences in the proportions of alpha red and alpha white fibers. Late castrates compared to early castrates had a 1.5% higher proportion of alpha red fibers and an equally lower proportion of alpha white fibers.

The basis for the differing results between trials due to castration time may be related to muscling differences between the genotypes. Lambs in Trial 1 are from genotypes selected primarily for prolificacy and production under forage management schemes and have less muscular development than lambs in Trial 2 which are comprised primarily of a genotype selected for carcass merit. Testosterone is known to stimulate muscular development (Florini, 1985), but its role in muscle growth has not been completely elucidated (Beitz, 1985). Ashmore et al. (1972) found transformation of alpha red to alpha white fibers in

lamb muscle began shortly after birth. Comparison of the early castrates to the later castrates and rams in Trial 1 showed the early castrates to have a higher proportion of alpha red and a lower proportion of alpha white fibers. These results compared with those of Trial 2 indicate that removal of the testes may have a more pronounced effect on muscle fiber transformation in the less heavily muscled genotypes than in genotypes which display greater muscular development.

Genotypic effects on proportions of muscle fiber types were small and inconsistent. Polypay lambs in Trial 1 had a 2.5% higher proportion of beta red fibers ($P<.05$), and a 3% lower proportion of alpha red fibers than the Coopworths. Alpha red fibers are larger in diameter than beta red fibers, and alpha white fibers are larger in diameter than alpha red fibers (Spindler et al. 1980; Solomon et al. 1981). Since fiber number/mm^2 does not significantly differ between the two genotypes, Polypay muscles have more beta red fibers and less alpha red fibers than the Coopworth which explains the more muscular appearance of the Coopworth genotype compared to the Polypay genotype. No differences were seen between genotypes in Trial 2.

Modest differences due to birthtype were observed in the two trials. Singles in Trial 1 have a significantly lower ratio of alpha red to alpha white fibers ($P<.05$) due

to both a lower proportion of alpha red fibers and a higher proportion of alpha white fibers. Differences between birthtypes in Trial 2 were nonsignificant. Fiber type proportions for both singles and twins in Trial 2 were similar to those of twins in Trial 1. The low alpha red to alpha white ratio of Trial 1 singles' suggests a greater transformation of alpha red to alpha white fibers, but provides no indication of a basis for increased transformation.

Comparison of the feeding regimens demonstrates an inconsistent effect on muscle fiber type proportions between the two trials. Trial 1 drylot lambs had a slightly lower proportion of alpha red fibers and a slightly higher proportion of alpha white fibers. Drylot lambs in Trial 2 had a 5% higher proportion of beta red fibers ($P<.01$) and demonstrated a tendency toward a lower proportion of alpha red fibers ($P<.10$).

No relationship between yield grade and muscle fiber proportions was seen in this experiment. This result fails to support the work of Hawkins et al. (1985b) who reported proportions of fiber types to be related to compositional indices. Their experiment involved only two genotypes and only compared early castrated wethers to ewes.

No age effects on muscle fiber type proportions were observed in these two trials. Lambs were slaughtered at ages ranging from 174 to 352 days. Age was not found to be significantly correlated to muscle fiber proportions. It

is likely that the transformation of alpha red to alpha white fibers observed by Ashmore et al. (1972) to begin shortly after birth was complete before the ages at which these animals were slaughtered.

A comparison of results from previous research looking at the effects of sex (Moody et al., 1980; Solomon et al., 1981; Hawkins et al., 1985b) and genotype (Solomon et al.,1980; Hawkins et al., 1985b) has shown lamb muscle fiber proportions to vary greatly between trials. Results within trials due to these factors have been inconsistent. Examination of the coefficients of variation before and after fitting the model in our trials indicates that less than 10% of the variation in the proportion of beta red fibers and less than 2% of the variation in the proportions of alpha red and alpha white fibers is explained by sex, time of castration, genotype, birthtype, feeding regimen and weaning weight.

Conclusion

Examination of several factors shown to significantly influence growth and carcass fatness (Arnold and Meyer, 1987a) found them to have minimal effect on proportions of the various muscle fiber types in the M. longissimus.

Residual variation in muscle fiber proportions was large even after accounting for sex, time of castration, genotype, birthtype, feeding regimen and weaning weight.

Furthermore, no significant relationships were found between muscle fiber proportions or ratios and estimators of carcass fatness. Such variation both indicates need for adequately large sample size in such studies and cautions against extrapolation of results beyond the scope of individual trials.

CHAPTER 5

CONCLUSION

Results from this experiment indicate lamb carcass yield to be highly negatively correlated to subcutaneous fat depth (Trial 1 r=-.96; Trial 2 r=-.93) and kidney-pelvic fat (Trial 1 r=-.61; Trial 2 r=-.53). Therefore to increase yield of lamb carcasses it is vital to reduce carcass fatness. This can be achieved most easily through the use of intact males, delaying castration, or a pasture feeding period during growth.

Ram lambs have higher daily gains, reduced carcass fatness and increased yield compared to both wethers and ewes, and produce a carcass of acceptable quality. Ram lambs from high growth rate breeds reach slaughter weight before sexual maturity and before increased growth of non-carcass parts, such as the head, which reduces carcass weight.

Delaying castration until a greater proportion of slaughter weight has been attained is also effective in reducing carcass fatness and increasing yields compared to early castrated wethers. Late castration does reduce ADG compared to rams, but gains are equal or higher than for early castrates. Delaying castration partially realizes the superior growth and carcass of ram lambs while avoiding the economic penalty currently imposed on ram lambs.

A pasture feeding period during growth reduces ADG

compared to drylot lambs. Yield is increased due to a reduction in subcutaneous and kidney-pelvic fat without a significant reduction in quality.

Use of meat type breeds increases growth rates and dressing percentage over results achieved with whiteface lambs. The dressing percentage advantage is due to superior muscling without increased fatness.

Many of the factors which affect growth and carcass development appear to have minimal influence on the M. longissimus fiber type proportions.

Transformation of the alpha red to alpha white fibers observed to begin shortly after birth does not appear to be a dynamic process throughout growth. Castration early in life appears to affect transformation, but exerts a more profound influence on genotypes that are less heavily muscled.

In almost all instances less than 2% of the variation observed in muscle fiber type proportions is explained by sex, time of castration, genotype, birthtype and weaning weight. Fiber number/mm^2 and fiber type proportions are not significantly correlated to age or any carcass traits measured in these trials. Thus no relationship appears to exist between muscle fiber proportions at slaughter and physiological maturity.

LITERATURE CITED

Adams, R. L., L. E. Walters, J. V. Whiteman and J. E. Fields. 1977. Feed efficiency and carcass characteristics of ram and ewe lambs slaughtered at two live weights. Oklahoma State Univ. Agr. Exp. Sta. Res. Rep. MP-101 p 114.

Arnold, A. M. and H. H. Meyer. 1987a. Effects of sex, time of castration, genotype, and feeding regimen on lamb growth and carcass fatness. J. Anim. Sci. submitted for publication.

Arnold, A. M. and H. H. Meyer. 1987b. Influences of sex, time of castration, genotype, birthtype, and feeding regimen on lamb muscle fiber type proportions. J. Anim. Sci. submitted for publication.

Ashmore, C. R., G. Tompkins and L. Doerr. 1972. Postnatal development of muscle fiber types in domestic animals. J. Anim. Sci. 34:37.

Beitz, D. C. 1985. Physiological and metabolic systems important to animal growth - an overview. J. Anim. Sci. 61 (Suppl. 2):1.

Berg, R. T., S. D. M. Jones, M. A. Price, R. Fukahara, R. M. Butterfield and R. T. Hardin. 1979. Patterns of carcass fat deposition in heifers, steers and bulls. Can. J. Anim. Sci. 59:359.

Blair, R. and P. R. English. 1965. The effect of sex on growth and carcass quality in the bacon pig. J. Agr. Sci. (Camb.) 64:169.

Botkin, M. D., D. A. Cramer. 1974. Genetic improvement of carcass merit in sheep. New Mexico Agr. Exp. Sta. Bull. 616.

Bowland, J. P., and R. T. Berg. 1959. Influence of strain and sex on the relationship of protein to energy in the rations of growing and finishing bacon pigs. Can J. Anim. Sci. 39:102.

Bowling, R. A., G. C. Smith, Z. L. Carpenter, T. R. Dutson and W. M. Oliver. 1977. Comparison of forage-finished and grain-finished beef carcasses. J. Anim. Sci. 45:209.

Boylan, W. J., Y. M. Berger and C. E. Allen. 1976. Carcass merit of Finnsheep crossbred lambs. J. Anim. Sci. 42:1413.

Bradford, G. E. and G. M. Spurlock. 1964. Effects of castrating lambs on growth and body composition. Anim. Prod. 6:291.

Bratzler, L. J., R. P. Soule Jr., E. P. Reinke and P. Paul. 1954. The effect of testosterone and castration on the growth and carcass characteristics of swine. J. Anim. Sci. 13:171.

Burton, J. H. and R. T. Reid. 1969. Interelationships among energy input, body size, age and composition of sheep. J. Nutr. 97:517.

Butler-Hogg, B. W., M. A. Francombe and E. Dransfield. 1984. Carcass and meat quality of ram and ewe lambs. Anim Prod. 39:107.

Butler-Hogg, B. W. and I. D. Johnsson. 1986. Fat partitioning and tissue distribution in crossbred ewes following different growth paths. Anim. Prod. 42:65.

Butterfield, R. M., J. Zamora, J. M. Thompson and K. J. Reddacliff. 1984. Changes in body composition relative to weight and maturity of Australian Dorset Horn rams and wethers. 1. Carcass muscle, fat, bone and body organs. Anim. Prod. 39:251.

Butterfield, R. M., J. M. Thompson and K. J. Reddacliff. 1985. Changes in body composition relative to weight and maturity of Australian Dorset Horn rams and wethers. 3. Fat partitioning. Anim. Prod. 40:129.

Cahill, V. R., H. S. Teague, L. E. Kunkle, A. L. Moxon and E. A. Rutledge. 1960. Measurement of and ways of affecting sex-influenced performance of growing finishing swine. J. Anim. Sci. 19:1036.

Calkins, C. R., T. R. Dutson, G. C. Smith, Z. L. Carpenter and G. W. Davis. 1981. Relationship of fiber type composition to marbling and tenderness of bovine muscle. J. Food Sci. 46:708.

Charette, L. A. 1961. The effects of sex and age of male at castration on growth and carcass quality of Yorkshire swine. Can. J. Anim. Sci. 41:30.

Collins, D. A. 1982. Effects of growth, feed efficiency and carcass traits of crossbred lambs slaughtered at three weights. M. S. Thesis Oregon State Univ., Corvallis.

Cornforth, D. P., A. L. Hecker, D. A. Cramer, A. A. Spindler and M. M. Mathias. 1980. Maturity and its relationship to muscle characteristics of cattle. J. Anim. Sci. 50:75.

Crouse, J. D., R. A. Field, J. L. Chant Jr., C. L. Ferrell, G. M. Smith and V. L. Harrison. 1978. Effect of dietary energy intake on carcass composition and palatability of different weight carcasses from ewe and ram lambs. J. Anim. Sci. 47:1207.

Crouse, J. D., J. R. Busboom, R. A. Field and C. L. Ferrell. 1981. The effects of breed, diet, sex, location and slaughter weight on lamb growth, carcass composition and meat flavor. J. Anim. Sci. 53:376.

Dahmen, J. J., D. D. Hinman, J. A. Jacobs and D. O. Everson. 1977. A comparison of Suffolk sired lambs produced by Panama and Finn x Panama dams. Proc. Western Sec. Am. Soc. Anim. Sci. 28:25.

Dalton, D. C. and L. R. Ackerley. 1974. Performance of sheep on New Zealand hill country. I. Growth and wool production of five breeds. New Zealand Agr. Res. 17:279.

Dickerson, G. E., H. A. Glimp, H. J. Tuma and K. E. Gregory. 1972. Genetic resources for efficient meat production in sheep growth and carcass characteristics of ram lambs of seven breeds. J. Anim. Sci. 34:940.

Doney, J. M. 1967. The effect of inbreeding on food consumption and utilization by sheep. Anim. Prod. 9:359.

Ely, D. G., B. P. Glenn, M. Mahyuddin, J. D. Kemp. F. A. Thrift and W. P. DeWeese. 1979. Drylot vs. pasture: early weaned lamb performance to two slaughter weights. J. Anim. Sci. 48:32.

Everitt, G. C. and K. E. Jury. 1966. Effects of sex and gonadectomy on the growth and development of Southdown x Romney cross lambs. I. Effects on live-weight growth and components of live weight. J. Agr. Sci. (Camb.) 66:1.

Florini, J. R. 1985. Hormonal control of muscle cell growth. J. Anim. Sci. 61 (Suppl. 2):21.

Garrigus, U. S., R. J. Vatthauer, E. E. Hatfield, B. B. Doane, J. H. Sokolowski and W. R. Usborne. 1962. Some effects of sex on rate of gain and carcass quality in young lambs. Proc. Western Sec. Am. Soc. Anim. Sci. 13:XXXIX.

Glimp, H. A. 1971. Effect of sex alteration, breed, type of rearing and creep feeding on lamb growth. J. Anim Sci. 32:859.

Gregory, K. E. and J. J. Ford. 1983. Effects of late castration, zeranol and breed group on growth, feed efficiency and carcass characteristics of late maturing bovine males. J. Anim. Sci. 56:771.

Gregory, K. E., S. C. Seideman and J. J. Ford. 1983. Effects of late castration, zeranol and breed group on composition and palatability characteristics of longissimus muscle of the bovine male. J. Anim. Sci. 56:781.

Gunsett, F. C., D. H. Baik, J. J. Rutledge and E. R. Hauser. 1981. Selection for feed conversion on efficiency and growth in mice. J. Anim. Sci. 52:1280.

Hammond, J. 1920. On the relative growth and development of various breeds and crosses of cattle. J. Agr. Sci. (Camb.) 10:233.

Hammond, J. 1932. Growth and Development of Mutton Qualities in the Sheep. Biological Monographs and Manuals. Oliver and Boyd, London.

Hawkins, R. R., J. D. Kemp, D. G. Ely, J. D. Fox, W. G. Moody and R. J. Vimini. 1985a. Carcass and meat characteristics of crossbred lambs born to ewes of different genetic types and slaughtered at different weights. Livestock Prod. Sci. 12:241.

Hawkins, R. R., W. G. Moody and J. D. Kemp. 1985b. Influence of genetic type, slaughter weight and sex on ovine muscle fiber and fat cell development. J. Anim. Sci. 61:1154.

Hedrick, H. B., G. B. Thompson and G. F. Krause. 1969. Comparison of feedlot performance and carcass characteristics of half-sib bulls, steers and heifers. J. Anim. Sci. 29:687.

Hedrick, H. B., J. A. Paterson, A. G. Matches, J. D. Thomas, R. E. Morrow, W. C. Stringer and R. J. Lipsey. 1983. Carcass and palatability characteristics of beef produced on pasture, corn silage and corn grain. J. Anim. Sci. 57:791.

Herriman, R. D., R. L. Adams, L. E. Walters, J. V. Whiteman and J. E. Fields. 1978. Comparison of feed efficiency for two weight intervals and carcass composition at two market weights of ram and ewe lambs. Oklahoma State Univ. Agr. Exp. Sta. Res. Rep. MP-103 p 140.

Hodgson, J. 1984. Sward conditions, herbage allowance and animal production: an evaluation of research results. Proc New Zealand Soc. Anim. Prod. 44:99.

Hulet, C. V., S. K. Ercanbrack and A. D. Knight. 1984. Development of the Polypay breed of sheep. J. Anim. Sci. 58:15.

Hunt, W. E., D. Meade and B. E. Carmichael. 1938. Effect of castration of lambs on their development and quality of meat. Maryland Agr. Exp. Sta. Bull. 417 p 259.

Jagusch, K. T., R. M. Mitchell, G. R. McConnell, P. F. Fennessy, M. R. Woodlock and N. P. W. Jay. 1971. Nutrition of the young growing lamb: studies at Lincoln College. Proc. New Zealand Soc. Anim. Prod. 31:121.

Jagusch, K. T., R. V. Rattray, T. W. Oliver and N. R. Cox. 1979. The effect of herbage yield and allowance on growth and carcass characteristics of weaned lambs. Proc. New Zealand Soc. Anim. Prod. 39:254.

Johnston, D. M., W. G. Moody, J. A. Boling and N. W. Bradley. 1981. Influence of breed type, sex, feeding system and muscle bundle size on bovine fiber type characteristics. J. Food Sci. 46:1760.

Jones, S. D. M., M. A. Price and R. T. Berg. 1980. Fattening patterns in cattle. I. Fat partitioning among the depots. Can. J. Anim. Sci. 60:843.

Jones, S. D. M. 1982. The accumulation and distribution of fat in ewe and ram lambs. Can. J. Anim. Sci. 62:381.

Kemp, J. D., J. D. Crouse, W. DeWeese and W. G. Moody. 1970. Effect of slaughter weight and castration on carcass characteristics of lambs. J. Anim. Sci. 30:348.

Kirton, A. H., D. C. Dalton and L. R. Ackerley. 1974. Performance of sheep on New Zealand hill country. II. Growth and composition of wethers of five breeds at three ages. New Zealand J. Agr. Res. 17:283.

Klosterman, E. W., L. E. Kunkle, P. Gerlaugh and V. R. Cahill. 1954. The effect of age of castration upon rate and economy of gain and carcass quality of beef calves. J. Anim. Sci. 13:817.

LaFlamme, L. F., A. Trenkle and D. G. Topel. 1973. Effect of castration or breed type on growth of the longissimus muscle in male cattle. Growth 37:249.

Lirette, A., J. R. Seoane, F. Minvielle and D. Froehlich. 1984. Effects of breed and castration on conformation, classification, tissue distribution, composition and quality of lamb carcasses. J. Anim. Sci. 58: 1343.

Lloyd, W. R., A. L. Slyter and W. J. Costello. 1980. Effect of breed, sex and final weight on feedlot performance, carcass characteristics and meat palatability of lambs. J. Anim. Sci. 51:316.

Magid, A. F., V. B. Swanson, J. S. Brinks, G. E. Dickerson and G. M. Smith. 1981a. Border Leicester and Finnsheep crosses. I. Survival, growth and carcass traits of F_1 lambs. J. Anim. Sci. 52:1253.

Magid, A. F., V. B. Swanson, J. S. Brinks, G. E. Dickerson and G. M. Smith. 1981b. Border Leicester and Finnsheep crosses. III. Market lamb production from crossbred ewes. J. Anim. Sci. 52:1272.

Makarechian, M., A. W. Munson, L. E. Walters and J. V. Whiteman. 1977. Some relationships between measures of growth and carcass coposition in lambs. Oklahoma State University Agr. Exp. Sta. Res. Rep. MP-101 p 120.

May, M. L., M. E. Dikeman and R. Schalles. 1977. Longissimus muscle histological characteristics of Simmental x Angus, Hereford x Angus and Limousin x Angus crossbred steers as related to carcass composition and meat palatability traits. J. Anim Sci. 44:571.

Miller, L. R., V. A. Garwood and M. D. Judge. 1975. Factors affecting porcine fiber type, diameter and number. J. Anim. Sci. 41:66.

Moody, W. G., J. D. Kemp, M. Mahyuddin, D. M. Johnston and D. G. Ely. 1980. Effect of feeding systems, slaughter weight and sex on histological properties of lamb carcasses. J. Anim. Sci. 50:249.

Ockerman, H. W., D. Jaworek, B. VanStavern, N. Parrett and C. J. Pierson. 1984. Castration and sire effects on carcass traits, meat palatability and muscle fiber characteristics in Angus cattle. J. Anim. Sci. 59:981.

Oliver, W. M., Z. L. Carpenter, G. T. King and J. M. Shelton. 1967. Qualitative and quantitative characteristics of ram and ewe lamb carcasses. J. Anim. Sci. 26:307.

Pålsson, H. and J. B. Vergès. 1952. Effects of the plane of nutrition on growth and the development of carcass quality in lambs. J. Agr. Sci. (Camb.) 42:1.

Peacock, F. M., A. Z. Palmer, J. W. Carpenter and M. Koger. 1979. Breed and heterosis effects on carcass characteristics of Angus, Brahman, Charolais and crossbred steers. J. Anim. Sci. 49:391.

Prescott, J. H. D. 1969. The influence of castration on growth of lambs in relation to plane of nutrition. In: D. N. Rhodes (Ed.) Meat Production from Entire Male Animals. pp 109-128. J. and A. Churchill Ltd., London.

Prescott, J. H. D. and G. E. Lamming. 1964. The effects of castration on meat production in cattle, sheep and pigs. J. Agr. Sci. (Camb.) 63:341.

Prescott, J. H. D. and G. E. Lamming. 1967. The influence of castration on the growth of male pigs in relation to high levels of dietary protein. Anim. Prod. 9:535.

Preston, T. R., I. Greenhalgh and N. A. MacLeod. 1960. The effect of hexoestrol on growth, carcass quality, endocrines and reproductive organs of ram, wether and female lambs. Anim. Prod. 2:11.

Purchas, R. W. 1978. Some effects of nutrition and castration on meat production from male Suffolk cross (Border Leicester-Romney cross) lambs. I. Growth and carcass quality. New Zealand J. Agr. Res. 21:367.

Reid, J. T., A Bensadoun, L. S. Bull, J. H. Burton, P. A. Gleeson, I. K. Han, Y. D. Joo, D. E. Johnson, W. R. McManus, O. Paladines, J. Q. Stroud, H. F. Tyrell, B. D. H. Van Niekerk and G. H. Wellington. 1968. Some peculiarities in the body composition of animals. In: Body Composition in Animals and Man. pp 19-44. Natl. Acad. Sci., Washington, D. C.

Robertson, I. S. 1966. Castration in farm animals: its advantages and disadvantages. Vet. Rec. 78:130.

SAS Institute Inc. 1985. SAS/STAT Guide for Personal Computers Version 6 Edition. Cary, NC.

Shelton, M. and Z. L. Carpenter. 1972. Influence of sex, stilbestrol treatment and slaughter weight on performance and carcas traits of slaughter lambs. J. Anim. Sci. 34:203.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical Methods (7th Ed.). Iowa State Univ. Press, Ames.

Solomon, M. B., W. G. Moody, J. D. Kemp and D. G. Ely. 1980. Effect of breed, slaughter weight and sex on histological properties of ovine muscle. J. Anim. Sci. 52:1019.

Solomon, M. B. and M. C. Dunn. 1987. Simultaneous histochemical determination of three fiber types in single sections of bovine, ovine and porcine skeletal muscle. J. Anim. Sci. (in press).

Spindler, A. A., M. M. Mathias and D. A. Cramer. 1980. Growth changes in bovine muscle fiber types as influenced by breed and sex. J. Food Sci. 45:29.

Staun, H. 1963. Various factors affecting number and size of muscle fibers in the pig. Acta Agr. Scand. 13:293.

Steel, R. G. D. and J. H. Torrie. 1980. Priciples and Procedures of Statistics (2nd Ed.). McGraw-Hill Book Co., New York.

Sutherland, T. M. 1965. The correlation between feed efficiency and rate of gain, a ratio and its denominator. Biometrics 21:739.

Swatland, H. J. 1977. Transitional stages in the histochemical development of muscle fibers during post-natal growth. Histochemical Journal 9:751.

Thomas, D. L., J. V. Whiteman and L. E. Walters. 1976. Carcass traits of lambs produced by crossbred dams of Finnsheep, Dorset and Rambouillet breeding and slaughterd at two weights. J. Anim. Sci. 43:373.

Thompson, J. M., K. D. Atkins and A. R. Gilmour. 1979. Carcass characteristics of heavyweight crossbred lambs. III. Distribution of subcutaneous fat, intermuscular fat, muscle and bone in the carcass. Aust. J. Agr. Res. 30:1215.

Thompson, K. F., J. C. McEwan and W. H. Risk. 1980. Pasture allowance and lamb growth. Proc. New Zealand Soc. Anim. Prod. 40:92.

Trenkle, A., P. L. DeWitt and D. G. Topel. 1978. Influence of age, nutrition and genotype on carcass traits and cellular development of the M. longissimus of cattle. J. Anim. Sci. 46:1597.

Turton, J. D. 1969. The effect of castration on meat production from cattle, sheep and pigs. In: D. N. Rhodes (Ed.) Meat Production From Entire Male Animals. pp 1-50. J. and A. Churchill Ltd., London.

Unruh, J. A. 1986. Effects of endogenous and exogenous growth-promoting compounds on carcass composition, meat quality and meat nutritional value. J. Anim. Sci. 62:1441.

Utley, P. R. and W. C. McCormick. 1976. Corn or Grain Sorghum for finishing steers in drylot or on rye pastures. J. Anim. Sci. 43:1141.

Vaughan, H., Aziz-Ullah, G. Goldspink and N. W. Nowell. 1974. Sex and stock differences in histochemical myofibrillar adenosine triphosphatase reaction in the soleus muscle of the mouse. J. Histochem and Cytochem. 22:155.

Wood, J. D., H. J. H. MacFie, R. W. Pomeroy and D. J. Twinn. 1980. Carcass composition in four sheep breeds: the importance of breed and stage of maturity. Anim. Prod. 30:135.

Wood, J. D. 1982. Factors controlling fat deposition in meat animals. Proc New Zealand Soc. Anim Prod. 42:113.

Worrell, M. A., D. C. Clanton and G. R. Calkins. 1987. Effect of weight and castration on steer performance in the feedlot. J. Ani. Sci. 64:343.

APPENDIX

Appendix 1. Least Squares Analysis of Variance for Growth and Carcass Traits (Trial 1)

		MEAN SQUARES									
Source	df	ADG[b]	CW/DA[c]	CCW	DRESSING %	FAT[c] DEPTH	KP[a] %	REA[b]	LEGSCORE[a]	USDA[a] QUALITY GRADE	USDA[a] YIELD GRADE
Castration	3	4.63	0.33	10.33	26.63	95.52	56.00	4.95	29.24	10.71	67.17
Genotype	1	1.48	0.52	3.67	0.45	24.51	4.44	82.59	0.19	1.15	7.56
Feedtype	1	29.20	17.80	23.89	16.41	44.68	36.97	0.34	0.92	1.77	36.26
C x G	3	3.22	1.24	10.57	5.37	11.93	24.09	25.27	1.53	3.80	7.35
C x F	3	0.70	0.03	0.31	1.07	14.95	25.68	11.11	1.48	6.36	14.13
G x F	1	2.37	0.07	0.03	0.25	0.05	0.02	6.43	0.36	0.84	0.02
C x G x F	3	2.34	0.07	5.80	7.85	7.60	12.87	8.08	15.00	4.45	6.67
Covariate	1	4.24	22.13	7.65	0.06	28.76	48.42	0.60	26.98	0.03	25.70
Residual	58	0.83	0.32	5.63	4.57	8.77	8.03	6.40	10.09	6.67	5.48

[a] value x 10^{-1}
[b] value x 10^{-2}
[c] value x 10^{-3}

Appendix 2. Least Squares Analysis of Variance for Growth and Carcass Traits (Trial 2)

		MEAN SQUARES									
Source	df	ADG[c]	CW/DA[c]	CCW	DRESSING %	FAT[c] DEPTH	KP[a] %	REA[b]	LEGSCORE[a]	USDA[a] QUALITY GRADE	USDA[a] YIELD GRADE
Castration	2	1.25	0.16	0.05	4.14	100.80	69.07	9.58	6.21	2.02	75.27
Genotype	1	0.01	0.59	0.49	0.96	0.40	21.15	21.68	11.21	0.57	0.79
Feedtype	1	477.78	28.99	51.96	45.04	0.34	36.72	9.76	7.45	0.23	0.98
C x G	2	0.44	0.12	2.30	5.15	5.27	33.62	1.02	0.06	2.82	6.74
C x F	2	0.31	0.01	5.47	2.85	2.26	8.57	4.03	10.37	2.78	0.89
G x F	1	48.91	0.13	14.12	11.88	0.00	9.98	6.52	23.05	0.01	0.99
C x G x F	2	13.01	0.09	2.58	12.12	4.08	1.64	0.14	0.17	2.58	2.25
Covariate	1	136.74	29.14	104.65	47.91	0.25	55.34	43.49	9.78	7.17	4.13
Residual	45	14.50	0.44	6.51	2.40	6.57	7.02	10.96	10.10	6.46	3.39

[a] value x 10^{-1}
[b] value x 10^{-2}
[c] value x 10^{-3}

Appendix 3. Least Squares Analysis of Variance for Muscle Fiber Parameters (Trial 1)

		MEAN SQUARES				
Source	df	FIBERS/mm^2	%βR	%αR	%αW	αR:αW[b]
Castration	3	915.41	17.32	211.57	119.14	42.67
Genotype	1	3249.90	63.19	92.47	2.78	5.46
Birthtype	1	706.78	0.23	202.99	216.76	72.97
Feedtype	1	2173.18	0.25	17.92	13.95	7.14
C x G	3	3507.57	17.57	92.29	69.79	15.95
C x B	3	1525.24	6.19	28.33	12.94	4.25
C x F	3	2059.03	4.82	47.18	35.61	13.39
G x B	1	3956.13	21.11	97.89	28.11	11.58
G x F	1	332.11	12.15	3.38	28.32	7.65
B x F	1	9272.60	40.79	20.49	3.47	1.26
Weaning Wt.	1	2078.97	21.24	262.34	134.25	60.47
Residual	36	2185.13	16.32	65.22	35.82	13.25

[b] value x 10^{-2}

Appendix 4. Least Squares Analysis of Variance for Muscle Fiber Parameters (Trial 2)

		MEAN SQUARES				
Source	df	FIBERS/mm^2	%βR	%αR	%αW	αR:αW[b]
Castration	2	1277.86	6.21	23.11	8.46	2.93
Genotype	1	0.33	0.47	32.86	25.49	6.56
Birthtype	1	733.37	0.24	41.96	48.59	14.45
Feedtype	1	1270.05	150.44	174.03	0.86	14.94
C x G	2	517.70	15.91	33.47	18.09	5.95
C x B	2	2412.45	30.05	184.54	71.54	27.53
C x F	2	3106.62	4.90	11.80	24.50	3.12
G x B	1	2295.99	50.31	194.95	47.17	23.84
G x F	1	219.83	21.63	1.49	11.78	0.31
B x F	1	87.74	0.03	7.60	8.62	4.39
Weaning Wt.	1	4838.46	4.05	10.76	1.62	1.82
Residual	27	1465.62	15.00	48.00	29.54	9.37

[b] value x 10^{-2}