INFLUENCE OF AGE AND TESTOSTERONE LEVELS ON MASCULINE DEVELOPMENT IN RAMS

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ABSTRACT

Fifty wethers and 51 spring-born rams were divided into five groups and slaughtered at different seasons of the year at average ages of 271, 361, 459, 557 or 652 d to determine the age and season at which differences in secondary sex characteristics could be detected. Serum testosterone concentrations and testes weights were low in January when the rams were 271 d of age and again in April at 361 d of age. By July, at 459 d of age, testosterone concentrations and testes weights had peaked and then decreased the following November at 557 d and February at 652 d. In contrast with plasma testosterone concentrations and testes weights, buckiness scores, splenius to semimembranosus or semitendinosus muscle ratios, splenius muscle weights and neck and shoulder percentages were not seasonal. All of these measures increased significantly up to July and continued to increase slowly, but not significantly, thereafter. Muscle color and texture scores and rib eye color scores tended to increase in a linear manner for both rams and wethers as age increased. Subcutaneous fat from rams was yellower and softer than that from wethers over all age groups. Ram fat firmness did not change ($P > .05$) with age, and the only significant change in ram fat color was between the groups at 271 and 361 d of age. Overall, season of year coupled with higher levels of serum testosterone was related to initial development of secondary sex characteristics in ram lambs.

(Key Words: Sheep, Maturity, Testosterone, Masculinizing Effect, Rams.)

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Introduction

The presence of secondary sex characteristics such as enlarged necks and shoulders results in grade discounts (USDA, 1982) and lower prices for rams compared with wethers. In addition to grade discounts, ram carcasses exhibiting secondary sex characteristics have a higher proportion of their muscle mass in the lower-priced neck and shoulder region. Butterfield et al. (1984) have shown that neck and shoulder muscles of mature rams represent 26.7% of the total muscle weight, compared with 24.2% for wethers. Information on age at which these differences begin to occur and on the role of testosterone in masculinization is lacking. Because testes volume (Howles, 1982) and testosterone production (Yarney and Sanford, 1983; Lafortune et al., 1984) fluctuate by season of the year, masculine development in ram lambs may be more dependent on season of the year than on age. Lafortune et al. (1984) showed that for ram lambs born in March, peak concentrations of plasma testosterone were reached in September, when the lambs were 6 mo old. However, lambs born in September did not reach peak plasma testoster-

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one levels until the following September, when they were 12 mo old.

If plasma testosterone concentrations are responsible for secondary sex characteristics in ram lambs (Brannang, 1971; Lohse, 1973; Schanbacher et al., 1980; Field et al., 1985), then lambs born too late in the year to have fall seasonal increases in concentrations of plasma testosterone should not exhibit secondary sex characteristics until the next fall and should be more desirable from a grade and muscle distribution standpoint than those born earlier in the year. In this study male lambs born in late April and early May were studied to determine the age and season at which differences in secondary sex characteristics between rams and wethers could be detected. Wethers were used as controls to account for variations by age and season that may not be related to testosterone.

Materials and Methods

One hundred one ram lambs born in late April or early May 1985 were used. Fifty of these rams were castrated at birth, and lambs within each gender group were assigned randomly to one of five slaughter groups after weaning. Weaning occurred in mid-August for rams and in early September for wethers, and all lambs grazed on range pasture until October. Then wether lambs were placed on long alfalfa hay in a feedlot and ram lambs grazed alfalfa aftermath until mid-December; all animals were fed alfalfa hay during the winter. Diets subsequently consisted of alpine-sagebrush range in spring, summer and fall and long alfalfa hay hand-fed in a feedlot during winter. Rams were weaned and kept separate from wethers because ewe lambs were fed with the wethers. Ten wethers and 10 rams slaughtered January 21, 1986 averaged 271 d of age. Similar numbers were slaughtered April 22, 1986, July 29, 1986, November 5, 1986 and February 10, 1987 and averaged 361, 459, 557 and 652 d of age, respectively. Each of the first four slaughter groups consisted of five wethers and five rams from predominantly Rambouillet dams and Finnish Landrace rams and five wethers and five rams from predominantly Rambouillet dams and Suffolk rams. The fifth group was similar in breeding to the other groups, but one additional Finn crossbred ram was slaughtered on February 10, 1987, making a total of six for that group.

The sheep were fed at the U.S. Sheep Experiment Station, Dubois, ID and trucked to the University of Wyoming Stock Farm 2 d before slaughter to be shorn and rested. Live weights were recorded on shorn animals immediately before slaughter and hot weights were recorded as carcasses left the kill floor. Throughout the study, the same official representative from the Standardization Branch of the USDA scored carcass maturity, yield grade, quality grade, muscle color and texture, fat color, fat firmness and buckiness 24 h after slaughter. Buckiness score was based on degree of masculine development. The grader was instructed to look down the line of unidentified mixed ram and wether carcasses and discount carcasses with masculine development by either 1/3, 1/2, 2/3, one full grade or more.

Both splenius muscles were dissected from the neck and one semitendinosus and one semimembranosus muscle was dissected from the leg so that relative growth rate of these muscles could be calculated. The semitendinosus and semimembranosus muscles have relative growth rates of 1.04 and 1.23 in relation to total muscle weight from 18 kg to 100 kg live weight (Butterfield et al., 1984). Of the muscles in the neck and shoulder, the splenius muscle is the most responsive to testosterone (Brannang, 1971; Lohse, 1973; Field, 1985). Therefore, the relative weights of the splenius compared with the other muscles were used to reflect quantitative differences in masculine development between rams and wethers and over time.

Another objective measurement of masculinity was neck and shoulder percentage. Prior to dissection of the splenius muscles from the neck, that portion of the untrimmed carcass anterior to the sixth rib including the neck, shoulder, brisket and shank was weighed and expressed as a percentage of the cold carcass weight.

Jugular blood samples were collected from each animal the day after the sheep arrived at the University Stock Farm and again the next day immediately before slaughter. Individual samples from both days were centrifuged and the serum was collected and frozen at –15°C. Serum testosterone values (ng/ml) obtained from the two samples were averaged for each animal. These two samples of each of 10 rams reflected average concentrations of testosterone by age group. Protocols for radioimmunoassay

TABLE 1. MEANS BY AGE AND SLAUGHTER DATE FOR CHARACTERISTICS OF RAMS AND WETHERS (N = 101)

Item	Average age in days and slaughter date					
	271 (Jan. 21)	361 (April 22)	459 (July 29)	557 (Nov. 5)	652 (Feb. 10)	SE
Live wt, kg[d]						
Rams	41.2[a]	55.1[b]	68.9[c]	66.0[c]	69.8[c]	1.84
Wethers	47.5[a]	56.9[b]	67.4[c]	66.5[c]	68.4[c]	1.80
Hot carcass wt, kg[e]						
Rams	21.9[a]	28.8[b]	35.9[c]	35.7[c]	36.8[c]	1.16
Wethers	26.5[a]	31.1[b]	36.7[c]	37.3[c]	38.0[c]	1.15
Dressing, %[e]						
Rams	53.1[a]	52.3[a]	52.1[a]	54.1[a]	52.7[a]	.70
Wethers	55.8[a]	54.6[a]	54.4[a]	56.1[a]	55.5[a]	.70
Fat depth, mm[eh]						
Rams	1.3[a]	2.3[b]	3.6[c]	1.8[ab]	2.0[b]	.02
Wethers	4.3[a]	3.8[a]	6.6[b]	4.8[a]	2.8[a]	.02
Carcass maturity[fh]						
Rams	1.5[a]	1.9[b]	2.3[c]	3.1[d]	3.0[d]	.08
Wethers	1.5[a]	1.8[b]	2.7[c]	3.2[d]	2.7[c]	.08
Yield grade[e]						
Rams	1.8[a]	1.9[ab]	2.6[c]	2.2[b]	2.0[ab]	.19
Wethers	2.9[a]	2.5[a]	3.9[b]	3.3[ab]	2.6[a]	.19
Quality grade[egh]						
Rams	6.9[a]	6.5[a]	6.4[a]	4.3[b]	3.3[b]	.45
Wethers	7.6[ab]	8.0[b]	6.6[a]	6.5[a]	7.6[ab]	.44

[a,b,c]Means within a row with superscripts that do not have a common superscript letter differ ($P < .05$).

[d]Differences between gender groups overall were not significant ($P > .05$).

[e]Differences between gender groups overall were significant ($P < .05$).

[f]1.4 = A[40], 2.3 = B[30], 3.1 = yearling[10].

[g]4 = low Good, 5 = average Good, 6 = high Good, 7 = low Choice, 8 = average Choice.

[h]Significant gender × slaughter age interaction ($P < .05$).

for testosterone followed the procedure outlined by Murdoch and Dunn (1982). Coefficients of variation for intra- and inter-assays were both ≤9%.

Statistical analysis of the data was completed on rams and wethers using General Linear Model procedures (SAS, 1985). Factors included in the analysis of variance model were breed, age, gender and breed × age and gender × age interactions. Effects of gender within each age group were not tested statistically. Where significant breed, age or gender effects averaged across age were detected, differences were tested using paired comparisons.

Results and Discussion

Weights, dressing percentages, fat depths, carcass maturity scores and grades for rams and wethers slaughtered approximately every 100 d from 271 to 652 d are found in Table 1. Numerically, wethers were heavier than rams initially because wethers were weaned 3 wk later than rams and were fed alfalfa hay in a feedlot during the period when rams were grazed in fields of alfalfa aftermath. Ram lambs gain faster than wethers when both are fed high-energy diets (Field, 1971; Seideman et al., 1982), but when feed is limited, there is very little difference in gains between the two groups (Field, 1971).

Between January 21 and April 22, all lambs were fed long alfalfa hay in a feedlot and ram lambs tended to compensate for their slower weight gains during the earlier period. Both rams and wethers were grazing Western sage-alpine range when slaughtered at an average age of 459 d on July 29. Neither ram nor wether weights changed significantly ($P > .05$) after this date. Regardless of slaughter date, wethers averaged across slaughter dates had a higher dressing percentage than rams.

Fat depth over the center of the longissimus muscle at the 12th rib increased from January 21 to July 29 in rams and wethers, but values

TABLE 2. MEANS BY AGE AND SLAUGHTER DATE FOR SECONDARY SEX CHARACTERISTICS (N = 101)

	Average age in days and slaughter date					
Item	271 (Jan. 21)	361 (April 22)	459 (July 29)	557 (Nov. 5)	652 (Feb. 10)	SE
Testosterone, ng/ml[g]	.32[a]	.34[a]	1.70[d]	1.03[c]	.58[b]	.05
Testes wt, g	246.8[a]	301.9[a]	650.4[d]	536.8[c]	404.7[b]	38.1
Buckiness[h]	1.0[a]	1.2[a]	2.1[b]	2.2[b]	2.2[b]	.26
Ratio of splenius to semimembranosus wt, g[efi]						
Rams	.11[a]	.10[a]	.16[b]	.17[b]	.18[b]	.01
Wethers	.06[a]	.08[b]	.08[b]	.08[b]	.09[b]	.01
Ratio of splenius to semitendinosus wt, g[efj]						
Rams	.28[a]	.23[a]	.41[b]	.44[b]	.45[b]	.03
Wethers	.18[a]	.20[b]	.22[b]	.20[b]	.23[b]	.03
Splenius muscle wt, g[efj]						
Rams	29.8[a]	37.0[a]	76.7[b]	80.4[b]	87.7[b]	5.4
Wethers	21.9[a]	32.2[b]	38.0[cd]	36.2[c]	42.6[d]	5.3
Neck and shoulder, %[efk]						
Rams	34.1[a]	33.4[a]	38.0[b]	38.7[b]	39.2[b]	.46
Wethers	31.9[a]	32.6[a]	35.0[b]	35.6[b]	35.9[b]	.46

[a,b,c,d]Means with superscripts that do not have a common superscript letter differ ($P < .05$).

[e]Differences between gender groups overall were significant ($P < .05$).

[f]Significant gender within slaughter age interaction ($P < .05$).

[g]Data for rams only, plasma testosterone levels for wethers averaged .09 or less and these values are below the sensitivity for the assay.

[h]1 = not enough masculine development for grade discount; 2 = 1/3 of a quality grade discount for masculine development; 3 = 1/2 of a quality grade discount for masculine development.

[i]Ratio is based on the combined weights of both splenius muscles and one semimembranosus or semitendinosus muscle.

[j]Both splenius muscles included in mean.

[k]Untrimmed neck, shoulder, forshank and brisket weight divided by cold carcass weight × 100.

were greater ($P < .05$) in wethers, confirming previous research (Field, 1971; Seideman et al., 1982). After July, fat depth measurements decreased as forage quality decreased. Carcass maturity scores for both rams and wethers increased until November 5, when the sheep averaged 557 d of age. After 557 d, maturity scores decreased slightly, suggesting that maturity estimates (USDA, 1982) are related to level of nutrition as well as to age.

Yield grade scores for both rams and wethers indicated that lean, heavy carcasses can be produced when roughage diets are fed. Quality grades decreased after 459 d of age in rams, when they were classified as yearlings. The greater grade differences between ram and wether carcasses of older animals compared with those of younger animals were expected. Several studies reviewed by Field (1971) and Seideman et al. (1982) agree that only minor grade differences exist between carcasses from young rams and wethers.

Means for masculine development in rams are listed in Table 2. Concentrations of plasma testosterone for forage-fed ram lambs were low in January when the rams averaged 271 d of age and again in April at 361 d of age. Testosterone levels peaked July 29th at 459 d of age and then decreased by the November and February slaughter dates. Seasonality in concentrations of plasma testosterone in rams is well established (Amann and Schanbacher, 1983). Sanford et al. (1974) found that ram lambs had a fourfold increase in testosterone concentrations from mid-August through September when they were 7 to 8 mo and levels remained elevated during October and November before decreasing. Gromes and Joyce (1975) reported that testosterone concentrations in mature rams peaked in July and were lowest in December. Schanbacher and Ford (1976) reported that average testosterone concentrations in mature rams varied from 1.24 ng/ml during the nonbreeding season to 5.22 ng/ml in the breeding season. Lafortune et al. (1984) showed that for ram lambs born in March, peak concentrations of plasma testosterone were reached in September when the

TABLE 3. MEANS BY AGE AND SLAUGHTER DATE FOR CHARACTERISTICS OF FAT AND LEAN FROM RAMS AND WETHERS (N = 101)

Item	Average age in days and slaughter date					
	271 (Jan. 21)	361 (April 22)	459 (July 29)	557 (Nov. 5)	652 (Feb. 10)	SE
Muscle color and texture[eg]						
Rams	1.4[a]	1.7[a]	2.1[b]	3.0[d]	2.4[c]	.12
Wethers	1.4[a]	1.8[b]	2.6[c]	3.3[d]	2.8[c]	.11
Longissimus muscle color[efh]						
Rams	2.3[a]	3.1[b]	3.4[b]	3.1[b]	2.9[b]	.18
Wethers	2.3[a]	3.0[b]	3.9[cd]	3.6[c]	4.2[d]	.18
Fat color[efi]						
Rams	2.6[a]	4.0[b]	3.3[b]	3.8[b]	3.8[b]	.15
Wethers	2.0[a]	2.9[b]	2.0[ab]	2.6[ab]	2.1[a]	.15
Fat firmness[ej]						
Rams	3.2[a]	3.7[a]	3.5[a]	3.6[a]	3.3[a]	.23
Wethers	2.0[a]	2.6[b]	2.6[b]	3.0[b]	1.9[a]	.22

[a,b,c,d]Means with superscripts that do not have a common superscript letter differ ($P < .05$).

[e]Differences between gender groups overall were significant ($P < .05$).

[f]Significant gender within slaughter age interaction ($P < .05$).

[g]1.4 = A[40], 2.3 = B[30], 3.1 = yearling[10].

[h]1 = typical of A maturity lamb, 5 = typical of mature mutton.

[i]1 = White, 5 = Yellow.

[j]1 = Extremely firm, 5 = extremely soft.

lambs were 6 mo old. However, lambs born in September did not reach peak plasma testosterone concentrations until the following September. Schanbacher (1987) found that plasma testosterone concentrations in mature Suffolk rams generally decreased to less than 1 ng/ml during the nonbreeding season and then returned to breeding season values of >4 ng/ml the next fall.

Testes weights were highest on July 29 at 459 d of age when serum testosterone concentrations were highest and then decreased in concert with concentration of testosterone (Table 2). Mickelsen et al. (1982) reported that scrotal circumference of mature rams was largest from August through October and smallest in February. Scrotal circumference is influenced by photoperiod (Shrestha et al., 1983). Testes growth is more rapid in decreasing photoperiods, regardless of season, when rams are placed in a controlled environment (Lindsay et al., 1984). Skinner and Rowson (1968) showed that reproductive development of rams born in July/August was delayed compared with that of lambs born in February/March. Rams born in July/August had testes weights averaging 137 g after 6 mo compared with 242 g after 6 mo for lambs born in February/March.

In contrast to serum testosterone concentrations and testes weights, buckiness scores, splenius to semimembranosus or semitendinosus muscle ratios, splenius muscle weights and neck and shoulder percentages were not seasonal. All of these measures in rams increased up to July 29 as serum testosterone concentrations and testes weight peaked, but they did not decrease during the rest of the study. After secondary sex characteristics in ram carcasses develop, they remain constant even when plasma testosterone levels, thought to be responsible for their development, decrease (Brannang, 1971; Lohse, 1973; Schanbacher et al., 1980; Field et al., 1985). Because testes weights and testosterone concentrations can increase as early as 6 to 8 mo (Skinner and Rowson 1968; Sanford et al., 1974), secondary sex characteristics (Table 2) that are objectionable to the meat trade also should have increased at these ages. Lack of objectionable secondary sex characteristics until rams reached 459 d of age in late July in the current study probably is due to a retarded rate of maturity associated with limited roughage in lieu of high-concentrate diets during fall and winter feeding.

Characteristics of fat and lean from rams and wethers by age and slaughter date are found in Table 3. Muscle color and texture

scores were evaluated by examining the primary and secondary flank muscles (USDA, 1982). Longissimus muscle color was evaluated by appearance of the cut surface approximately 30 min after ribbing the carcasses at the 12th rib. These traits tended to increase in a linear manner for both rams and wethers as age increased. Differences in these characteristics between rams and wethers were small and were not consistent. Therefore, color and texture of lean does not appear to be influenced by levels of testosterone or development of secondary sex characteristics. Very little information on muscle color and texture or on rib eye color differences between carcasses from rams and wethers is available (Seideman et al., 1982).

In contrast to lean characteristics, where no consistent differences between rams and wethers were apparent, differences in color and firmness of the fat were sex-related. Subcutaneous fat tended to be yellower and softer for rams than for wethers. Kruggel et al. (1982) found that ram lambs fed a low-energy alfalfa diet accumulated much higher concentrations of lutein in their fat than did wethers fed the same diet. However, when high-energy diets low in lutein were fed, neither rams nor wethers accumulated significant quantities of lutein. They concluded that yellow fat, which is caused by high lutein levels, can be decreased by castration before lambs reach 60 d of age or by feeding a diet low in lutein. In our study, rams in the January slaughter group had whiter fat than did rams at the older ages. Lambs slaughtered in April had been fed alfalfa for several months, which would be expected to increase yellow fat intensity.

Fat firmness scores show that wether fat is firmer than ram fat. Softer fat in rams than in wethers is a result of higher levels of methyl branched-chain fatty acids and odd-numbered, straight-chain fatty acids in fat from rams (Busboom et al., 1981). In the present study, neither fat color nor fat firmness appeared to be related to season of slaughter.

Breed differences between the Suffolk × whiteface and Finn × whiteface crosses for each of the variables in all three tables were tested. With the exception of the heavier weight in the Suffolk crosses, no significant ($P > .05$) breed differences were observed. Finn crossbred ram lambs tended to have higher levels of plasma testosterone and slightly heavier testicle weights than did the Suffolk crosses.

Implications

Season of the year and sexual maturity coupled with higher levels of plasma testosterone are related to development of some objectionable secondary sex characteristics in ram carcasses. If the advantages of faster gain and leaner carcasses in rams are to be utilized in sheep production systems, rams will need to be slaughtered at an age before secondary sex characteristics become objectionable. Alternatively, producers may utilize fall lambing to produce rams that mature sexually at older ages than those born in the spring. Because longer photoperiods delay the increases in plasma testosterone levels and testes size, a third alternative for delaying sexual development is to expose young ram lambs to 16 h of light by supplementing natural light with artificial lighting during the summer and fall months preceding slaughter.

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