ADJUSTMENT FACTORS OF BIRTH WEIGHT AND FOUR POSTNATAL WEIGHTS FOR TYPE OF BIRTH AND REARING, SEX OF LAMBS AND DAM AGE

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ABSTRAK

SUBANDRIYO dan D.W. VOGT. 1995. Faktor koreksi untuk bobot lahir dan empat bobot badan pascalahir terhadap tipe kelahiran dan dibesarkan, jenis kelamin dan umur induk waktu beranak pada ternak domba. *Jurnal Ilmu Ternak dan Veteriner* 1 (1): 1-10.

Beberapa faktor mempengaruhi keragaman bobot badan domba. Beberapa faktor, seperti umur, jenis kelamin, tipe kelahiran dan dibesarkan serta umur induk waktu beranak sangat mempengaruhi perbedaan nilai genetik anak domba. Keragaman yang berhubungan dengan faktor-faktor tersebut akan menurunkan keefektifan seleksi untuk meningkatkan mutu genetik bobot badan. Untuk meningkatkan respon terhadap seleksi, seleksi harus didasarkan pada nilai genetik dan bukan didasarkan pada pengaruh lingkungan. Penelitian ini bertujuan untuk membentuk faktor koreksi terhadap setiap bangsa domba untuk bobot badan anak pascalahir. Data lapangan dari domba Suffolk dan Dorset yang dikumpulkan oleh "the U.S. National Sheep Improvement Program (NSIP)" dari tahun 1986 sampai dengan tahun 1989 digunakan untuk membuat faktor koreksi terhadap tipe kelahiran dan dibesarkan, jenis kelamin, dan umur induk waktu beranak unutk bobot lahir (BW) dan bobot anak 30-hari (W_{30}), 60-hari (W_{60}), 90-hari (W_{90}), dan 120-hari (W_{120}). Data dianalisis dengan menggunakan model linier. Faktor koreksi untuk setiap bangsa domba dan umur penimbangan dianjurkan digunakan, karena pertumbuhan yang beragam di antara bangsa domba dan keempat kelompok bobot badan pascalahir. Untuk setiap bangsa domba dianjurkan menggunakan faktor koreksi dalam bentuk perkalian terhadap pengaruh tipe kelahiran dan dibesarkan, jenis kelamin dan umur induk waktu beranak untuk bobot lahir dan keempat bobot badan pascalahir, karena ragam dari faktor-faktor tersebut heterogen ($P<0,01$).

Kata kunci: Domba, faktor koreksi, bobot lahir, bobot pascalahir

ABSTRACT

SUBANDRIYO and D.W. VOGT. 1995. Adjustment factors of birth weight and four postnatal weights for type of birth and rearing, sex of lambs and dam age. *Jurnal Ilmu Ternak dan Veteriner* 1 (1): 1-10.

Many factors contribute to variation in lamb weights. Factors such as age of lamb, sex, type of birth and rearing, and ewe age at lambing obscure genetic differences among lambs. Variation associated with these factors make selection for increased weight less effective. To improve selection response, selection must be based on genotypic rather than environmentally induced superiority. It is well-documented that corrections for classifiable sources of variation render selection and culling more accurate, thereby increasing rates of genetic improvement. The objective of this study were to develop within breed adjustment factors for post-natal lamb weights. Field records from Suffolk and Dorset lambs collected in the U.S. National Sheep Improvement Program (NSIP) from 1986 through 1989 were used to develop within-breed birth/rearing type, lamb sex, and dam age adjustment factors for birth weight (BW) and 30-d (W_{30}), 60-d (W_{60}), 90-d (W_{90}), and 120-d (W_{120}) weights. Data were analyzed using general linear models. Within breed and age group adjustment for lamb-age differences were suggested because growth rates vary among breeds and among the four postnatal lamb-age groups. Within-breed multiplicative adjustment of the five traits for the effects of birth/rearing type, lamb sex and dam age were suggested because variances of these factors were significantly ($P<0.01$) heterogenous.

Key words: Sheep, adjustment factors, birth weight, postnatal weights

INTRODUCTION

Lamb weight is an economically important trait in sheep production. Maximizing total weight of lambs weaned and marketed per ewe is one of the objectives of sheep producers. The importance attributed to weight in individual lambs is related directly to cash value.

Many factors contribute to variation in lamb weights. Factors such as age of lamb, sex, type of birth and rearing, and ewe age at lambing obscure genetic differences among lambs. Variation associated with these factors make selection for increased weight less effective. To improve selection response, selection must be based on genotypic rather than environmentally induced superiority. It is well-documented that corrections for classifiable sources of variation render

selection and culling more accurate, thereby increasing rates of genetic improvement (NOTTER *et al.*, 1975).

LUSH and SHRODE (1950) indicate that the primary purpose of data adjustment is to remove phenotypic differences associated with environmental conditions not conforming to those of a chosen standard. They define an adjustment factor as a statistical control to be used instead of a physical control not actually achieved.

Adjustment factors can be multiplicative or additive. Both types effectively equalize means, but multiplicative adjustment alters variance in proportion to the square of the factor. Additive adjustment does not change the variance. Adjustment factors currently used in the U.S. National Sheep Improvement Program (NSIP) are multiplicative and are a combination of factors calculated by the USDA (1968), NOTTER *et al.* (1975), and MARTIN *et al.* (1980). These adjustments are used for all weaning ages and breeds.

The objectives of this study were to develop multiplicative and additive adjustment factors for individual breed. In this study adjustment factors are developed for Suffolk, a large breed, and Dorset, a smaller breed.

MATERIALS AND METHODS

Data description

The Suffolk and Dorset data for this study were from field records of the National Sheep Improvement Program (NSIP) from 1986-1989. Data were collected from flocks throughout the United States, although most were from the Midwest and Northwest. The weights included birth weight (BW) and postnatal weights recorded for 30-d (W30), 60-d (W60), 90-d (W90), and 120-d (W120) of age. Ages of postnatal weights were 16-44 days for W30; 32 to 88 days for W60, 60 to 118 days for W90 and 92 to 148 days for W120.

Lambs with weight records, but with an unknown sire or dam were edited from the data set. Data on quadruplet born and triplet-born lambs raised as singles were removed from the data set because of insufficient numbers across subclasses. Additionally lambs artificially reared or fostered by another dam were omitted. Flocks with single sires were not included in the analysis. Flock-year-season-management subsets with fewer than 4 animals also were edited from the data set.

Year was designated as year of birth and season was designated as spring (January 1 to June 30) or fall (July 1 to December 31). Management in this data set was type of feeding given to the dam and lambs which included lambs not creep fed-dam fed in accordance with number of lambs nursed; lambs creep fed-dam fed in accordance with number of lambs nursed; lambs not creep fed-dam not fed in accordance with number of lambs nursed; lambs creep fed-dam not fed in accordance with number of lambs nursed.

Dam age at lambing was categorized into 7 different ages namely less than 19 months of age; 19 -30 months of age; 31 to 42 months of age; 43 to 54 months of age; 55 to 66 months of age; 67 to 78 months of age; and greater than 78 months of age.

Type of birth and rearing categorized as single-born and raised as a single; twin-born and raised as a single; twin-born and raised as twins; triplet-born and raised as twins; and triplet born and raised as triplets. Sex in this data set included male and female for birth and postnatal weights, and male, female and wether for postnatal weights.

Statistical methods

Preliminary analyses were conducted to examine main effects (contemporary group which was flock-year-season-management subset; birth type or type of birth and rearing, sex of lamb and dam age at lambing) and two factor interactions among these main effects influencing BW, W30, W60, W90, and W120. Additionally, these analyses were conducted to evaluate linear and quadratic effects of lamb age on W30, W60, W90, and W120. Results of the preliminary analyses showed that the main effects were mostly importance sources of variation both for Suffolk and Dorset data, while two factor interaction between main effects accounted for less than 2% of the total variation. Therefore, only main effects were considered in subsequent analyses.

Linear regression effects, relative to quadratic regression effects, accounted for a greater proportion of total variation associated with each postnatal weights for Suffolk (5.4 to 10.7% vs 0.02 to 0.38%) and Dorset (1.5 to 12.5% vs 0.07 to 0.36%) data. Fitting linear regressions as covariate for Suffolk and Dorset data consistently yielded a significant ($P<0.001$) age effect on each of the four postnatal weights. These results suggest that postnatal growth of Suffolk and Dorset, for the ages concerned, was essentially linear. Therefore, it was decided to consider only linear regression effects in subsequent analyses.

To account for variation due to lamb age in the four postnatal weights, postnatal growth rates were calculated as linear regressions of W30, W60, W90, W120 on lamb age at weighing. The following linear statistical model was employed to obtain these regression coefficients (SAS, 1985).

$WT_{ijklm} = \mu + CGi + Tj + Sk + Al + b\ (Ageijklm) + \varepsilon_{ijklm}$

where: WT_{ijklm} = observation of the m^{th} W30, W60, W90, or W120 in the j^{th} type of birth and rearing, k^{th} sex and l^{th} dam age groups; μ = overall population mean for any of the four postnatal weights; CG_i = fixed effect of the i^{th} contemporary group; T_j = fixed effect of the j^{th} type of birth and rearing; S_k = fixed effect of the k^{th} sex; A_l = fixed effect of the m^{th} dam age; b = linear regression coefficient; Age_{ijklm} = effect of covariable age of lamb; ε_{ijklm} = random residual error term.

Postnatal weights, then, were adjusted to an age constant basis using the following formula.

Age-adjusted weight = Weight + b (Constant age - Age)

where: Age-adjusted weight is the age-adjusted value for W30, W60, W90, or W120; Weight is the actual W30, W60, W90, or W120; b is the linear regression for W30, W60, W90, or W120 obtained from previous analyses; Constant age is 30, 60, 90, or 120 days; Age is the actual age (days) of the lamb at weighing.

To account for phenotypic differences associated with birth type or type of birth and rearing, sex of lamb and dam age at lambing, additive and multiplicative adjustment factors for these effects were developed simultaneously after correcting W30, W60, W90, and W120 to a lamb age constant basis. The linear statistical model described below was employed to obtain the least squares means (LSM) for developing the correction factors (SAS, 1985).

$WT_{ijklm} = \mu + CG_i + T_j + S_k + A_l + ijklm$

where: WT_{ijklm} = observation of the m^{th} BW, age-adjusted W30, age-adjusted W60, age-adjusted W90, or age-adjusted W120 in the i^{th} contemporary group, j^{th} birth type or type of birth and rearing, k^{th} sex and l^{th} dam age groups; μ = overall population means for any of the four age-adjusted weights; CG_i = fixed effect of the i^{th} contemporary group; T_j = fixed effect of the j^{th} birth type for BW or type of birth and rearing for age-adjusted W30, W60, W90, or W120; S_k = fixed effect of the k^{th} sex; A_l = fixed effect of the l^{th} dam age groups; ε_{ijklm} = random residual error term.

Multiplicative adjustment factors for birth type in BW were developed as the ratio of the LSM for twin born lambs to the LSM of the birth type to be adjusted. For W30, W60, W90, and W120, multiplicative adjustment factors for type of birth and rearing were developed as the ratio of the LSM for lambs born and raised as twins to the LSM of the type of birth and rearing to be adjusted.

Multiplicative sex adjustment factors for BW, W30, W60, W90, and W120 were developed as the ratio of the LSM for males to the LSM for the sex to be adjusted.

Dam-age multiplicative adjustment factors for BW, W30, W60, W90, and W120 were based on the ratio of the LSM for the dam age that produced the maximum BW, W30, W60, W90, or W120 to the LSM for the dam age to be adjusted.

Additive adjustment factors for birth type for BW were calculated as the deviation of the LSM for lambs born as twins to the LSM of the birth type to be adjusted. For W30, W60, W90, and W120, type of birth and rearing additive adjustment factors were calculated as the difference between the LSM for lambs born and raised as twins and the LSM of the type of birth and rearing to be adjusted.

Additive sex adjustment factors for BW, W30, W60, W90, and W120 were determined as the deviation of the LSM of males from the LSM of the sex to be adjusted.

Age of dam additive adjustment factors for BW, W30, W60, W90, and W120 were developed as the deviation of the LSM of the dam age that produced the maximum BW, W30, W60, W90, or W120 from the LSM of the dam age to be adjusted.

To determine the applicability of the additive and multiplicative adjustment factors, tests for homogeneity of variance for BW, age-adjusted W30, W60, W90, and W120 for each class (birth type or type of birth and rearing, sex and dam age) were performed using Bartlet's test as described by SNEDECOR and COCHRAN (1989).

RESULTS AND DISCUSSIONS

Adjustment of postnatal weights to an age constant value

Analyses of variance and mean squares for unadjusted W30, W60, W90, and W120, respectively, showed that main effects (i.e. contemporary group which is flock-year-season-management effect, type of birth and rearing, sex of lamb and dam age) were significant ($P < 0.001$) for all weights in Suffolk lambs.

Using Dorset data, contemporary group, type of birth and rearing, and sex of lamb were significant ($P<0.001$), but level of significance of dam age effects varied among weight traits. Dam age effects were significant ($P<0.001$, $P<.001$, $P<0.01$) for W30, W60, and W90, respectively, and nearly significant ($P<0.10$) for W120. Linear regression effects of lamb age were significant ($P<0.001$) for all weights in both breeds.

Postnatal growth rates of the four weight traits range from 0.279 to 0.336 kg/d for Suffolk lambs, and from 0.227 to 0.308 kg/d for Dorset lambs. Growth rates for all four ages are greater for Suffolk lambs than Dorset lambs as expected since the Suffolk is classified a high growth rate breed, while the Dorset is classified a medium growth rate breed (Sheep Industry Development Program, Inc. (SID), 1988). Average postnatal growth rates also varied among the four lamb age groups. Average growth rates for W30, W60, W90, and W120 were 0.336 ± 0.019, 0.279 ± 0.013, 0.345 ± 0.016 and 0.320 ± 0.017 kg/d for Suffolks and 0.269 ± 0.033, 0.308 ± 0.013, 0.237 ± 0.038 and 0.227 ± 0.024 kg/d for Dorset. These findings indicate that lamb age adjustments should be made on a within-breed and within-age group basis.

Adjustment of birth weight and postnatal weights for birth type or type of birth and rearing, sex of lamb and dam age

Birth Weight

Analyses of variance and mean squares for birth weight showed that main effects (i.e. contemporary group which is flock-year-season effect, birth type, sex of lamb and dam age) consistently showed significance ($P<0.001$) in both breeds. Among these main effects, using Suffolk data, birth type contributed the largest amount of variation (16.4%) followed by contemporary group (14%), dam age (6.6%) and sex of lamb (2.1%). For Dorset lambs, contemporary group, birth type, sex of lamb and dam age contributed 23.7, 15.1, 2.9, and 2.0%, respectively, to the total variation of birth weght.

Birth weight least squares means with their standard errors and standard deviations by birth type, sex of lamb and dam age are given in Table 1. Variances of birth type and lamb sex were heterogeneous ($P<0.01$) in both breeds. Variances among dam age subclasses were heterogeneous ($P<0.01$) for Suffolks but not for Dorsets ($P>0.10$). These results suggest that for Suffolks multiplicative adjustment should be used for birth type, sex of lamb and dam age. However, for Dorsets, multiplicative adjustments are suggested for birth type and sex of lamb, and additive adjustments for dam age. Both multiplicative and additive adjustment factors effectively equalize means, but with heterogeneous variances among subclasses, multiplicative adjustment factors alter the variance in proportion to the square of the factor (LEWIS *et al.*, 1989).

Table 1. Number of observations (N), least squares means (LSM), standard errors (SE), and standard deviations (SD) for birth weight by breed, birth type (TB), sex of lamb, and dam age (DA)

Variable	Breed							
	Suffolk				Dorset			
	N	LSM	SE	SD	N	LSM	SE	SD
		..... kg				..... kg		
TB								
Single	1,312	6.4	0.03	1.18	794	5.2	0.03	1.04
Twin	4,034	5.4	0.02	1.01	1,724	4.3	0.02	0.87
Triplet	1,052	4.6	0.03	0.99	205	3.7	0.06	0.88
R^2(%)				16.4				15.1
Significance		***		**		***		**
Sex								
Ewe	1,145	5.3	0.02	1.09	1,309	4.2	0.03	0.96
Ram	3,253	5.6	0.02	1.16	1,414	4.5	0.03	1.03
R^2 (%)				2.1				2.0
Significance		***		**		***		**
Dam age								
1	826	4.7	0.04	1.09	238	3.9	0.06	1.08
2	1,536	5.3	0.03	1.16	566	4.2	0.04	1.04
3	1,362	5.6	0.03	1.12	553	4.4	0.04	1.00
4	1,092	5.7	0.03	1.14	494	4.5	0.04	0.95
5	704	5.7	0.04	1.04	335	4.5	0.05	0.99
6	433	5.6	0.05	1.12	249	4.6	0.05	0.98
≥ 7	445	5.6	0.05	1.04	288	4.6	0.05	1.04
R^2 (%)				6.6				2.9
Significance		***		**		***		NS

*** = $P<.001$; ** = $P<.01$; NS = non significance

Birth weight multiplicative and additive adjustment factors by breed, birth type, sex of lamb and dam age are given in Table 2. Single Suffolk lambs were 18% or 0.98 kg heavier than twins, and twins were 17% or 0.78 kg heavier than triplets in birth weight. For the Dorsets, single lambs were 20% or 0.88 kg heavier than twins, and twins were 16% or 0.59 kg heavier than triplets. Suffolk ram lambs were 6% or 0.33 kg heavier than ewe lambs and 7% or 0.29 kg heavier in

Dorset lambs. Curvilinear effects of dam age on birth weight were found for both breeds. Maximum birth weights, among Suffolk dams were produced by 4- and 5-yr-old females. Among Dorsets, maximum birth weights were produced by 6-yr-old dams.

Table 2. Within-breed multiplicative (MULT) and additive (ADD) adjustment factors for the effects of birth type (TB), sex of lamb and dam age on birth weight

Variable	Breed			
	Suffolk		Dorset	
	MULT	ADD, kg	MULT	ADD, kg
TB				
Single	0.85	-0.98	0.83	-1.94
Twin	1.00	0.00	1.00	0.00
Triplet	1.17	0.78	1.16	1.30
Sex				
Ewe	1.06	0.33	1.07	0.64
Ram	1.00	0.00	1.00	0.00
Dam age				
1	1.21	0.99	1.17	1.43
2	1.08	0.42	1.10	0.94
3	1.03	0.14	1.05	0.49
4	1.00	0.00	1.02	0.20
5	1.00	0.00	1.01	0.10
6	1.01	0.07	1.00	0.00
≥7	1.01	0.08	1.01	0.09

Weight at 30-d (W30)

Within-breed analyses of variance and mean squares for lamb age-adjusted 30-d weights (W30) showed that all main effects were significant ($P<0.001$) in both breeds. Among these main effects, using Suffolk data, contemporary group (i.e.flock-year-season-management effects) was the largest source of variation (19.3%) in W30 followed by type of birth and rearing (16.3%), dam age (6.2%) and sex of lamb (4.2%). Using Dorset data, contemporary group, type of birth and rearing, dam age and sex of lamb accounted for 27.7, 21, 3.3, and 2.1%, respectively, of the total variation in W30.

Least squares means, standard errors and standard deviations by breed, type of birth and rearing, sex of lamb and dam age for W30 are given in Table 3. Subset variances of type of birth and rearing were heterogeneous ($P<0.001$) in both breeds. Heterogeneous variances ($P<0.01$, $P<0.05$) were also observed in sex of lamb subclasses for Suffolk and Dorset breeds, respectively. Intra-dam age group variances for W30 also differed significantly ($P<.01$) from group to group for Suffolk lambs but not for Dorset lambs ($P>0.10$). Results suggest that for Suffolks multiplicative adjustments should be used for type of birth and rearing, dam age and sex of lambs for W30. For Dorsets, multiplicative adjustments are suggested for type of birth and rearing and sex of lambs and additive adjustments for dam age.

Table 3. Number of observations (N), least squares means (LSM), standard errors (SE), and standard deviations (SD) for age-adjusted 30-d weight by breed, type of birth and rearing (TBR), sex of lamb, and dam age (DA)

Variable	Breed							
	Suffolk				Dorset			
	N	LSM	SE	SD	N	LSM	SE	SD
		..... kg				..... kg		
TBR[a]								
11	282	18.8	0.17	3.31	150	15.4	0.20	2.88
21	63	16.4	0.32	3.37	30	12.9	0.40	3.04
22	837	15.7	0.12	2.92	343	12.2	0.15	2.26
32	99	14.6	0.27	2.77	16	11.4	0.56	3.11
33	98	13.4	0.27	2.86	15	10.3	0.58	2.22
R^2 (%)				16.3				21.0
Significance		***		**		***		**
Sex								
Ewe	691	15.1	0.10	3.00	264	12.0	0.22	2.69
Ram	377	16.6	0.18	3.62	220	12.9	0.22	3.04
Wether	311	15.6	0.19	2.96	70	17.0	0.35	2.27
R^2				4.2				2.1
Significance		***		**		***		*
Dam age								
1	226	13.9	0.21	3.64	54	11.2	0.36	3.20
2	352	15.3	0.17	3.14	115	12.6	0.29	3.05
3	297	16.0	0.18	2.96	112	13.2	0.29	2.68
4	226	16.6	0.20	3.20	112	12.8	0.26	2.64
5	145	16.5	0.23	3.03	73	12.9	0.31	2.49
6	70	16.3	0.31	3.59	35	12.4	0.39	2.81
≥7	63	15.9	0.36	3.11	53	12.0	0.34	3.31
Significance		***		*		***		NS

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.

*** = P<.001; ** = P<.01; * = P<.05; NS = non significance.

Within-breed multiplicative and additive adjustment factors for the effects of type of birth and rearing, sex of lambs and dam age on W30 are given in Table 4. Weights at 30-d of Suffolk lambs born and raised as singles were 14% or 2.39 kg, 20% or 3.14 kg, 29% or 4.17 kg and 41% or 5.43 kg heavier than lambs born twins and raised as singles, born and raised as twins,

triplet born and raised as twins, and born and raised as triplets, respectively. Corresponding differences for Dorset lambs were 19% or 2.49 kg, 25% or 3.15 kg, 34% or 3.97 kg and 49% or 5.1 kg. Weights at 30-d of Suffolk ram lambs were 10% or 1.52 kg and 8% or 0.94 kg heavier than Suffolk ewe and wether lambs, respectively. Corresponding differences for the Dorsets were 7% or 1.04 kg and 3% or 0.42 kg, respectively. Curvilinear effects of dam age on W30 were found in both breeds. Maximum W30 values were produced by 4- to 5-yr-old dams for Suffolks, and 3-yr-old dams for Dorsets.

Table 4. Within-breed multiplicative (MULT) And additive (ADD) adjustment factors for the effects of type of birth and rearing (TBR), sex of lamb and dam age on 30-d weight

Variable	Breed			
	Suffolk		Dorset	
	MULT	ADD, kg	MULT	ADD, kg
TBR[a]				
11	0.83	- 3.14	0.80	- 3.15
21	0.95	- 0.75	0.95	- 0.66
22	1.00	0.00	1.00	0.00
32	1.07	1.03	1.07	0.82
33	1.17	2.29	1.19	1.95
Sex				
Ewe	1.10	1.52	1.08	0.94
Ram	1.00	0.00	1.00	0.00
Wether	1.07	1.04	1.03	0.42
Dam age				
1	1.19	2.63	1.19	2.06
2	1.08	1.24	1.05	0.59
3	1.03	0.52	1.00	0.00
4	1.00	0.00	1.03	0.44
5	1.00	0.00	1.03	0.36
6	1.01	0.23	1.07	0.87
≥ 7	1.04	0.59	1.10	1.23

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.

Weight at 60-d (W60)

Analyses of variance and mean squares results for Suffolk and Dorset lamb age-adjusted W60 values showed that all main effects (i.e. contemporary group, type of birth and rearing, sex of lamb and dam age) are significant ($P<0.001$) in both breeds. Among these main effects, contemporary group contributed the largest source of variation (19.9%), followed by type of birth and rearing (4.7%), sex of lamb (3.2%) and dam age (2%) for Suffolk lambs. For Dorset lambs, contemporary group, type of birth and rearing, sex of lamb and dam age contributed 35.7, 10.4, 3.8, and 2%, respectively, to total variation.

Least squares means, standard errors and standard deviations for W60, by breed, type of birth and rearing, sex of lamb and dam age are given in Table 5. For Suffolks, heterogeneous ($P<0.01$) variances were found in all type of birth and rearing, sex of lamb and dam age subclasses. Using Dorset data, heterogeneity ($P<0.01$) of variances were found for sex of lamb and dam age subclasses. Variances of type of birth and rearing subclasses were nearly heterogeneous ($P<0.10$). These results suggest that multiplicative adjustments for W60 should be used for type of birth and rearing, sex of lamb and dam age for both Suffolk and Dorset data.

Table 5. Number of observations (N), least squares means (LSM), standard errors (SE) and standard deviations (SD) for age-adjusted 60-d weight by breed, type of birth and rearing (TBR), sex of lamb, and dam age (DA)

Variable	Breed							
	Suffolk				Dorset			
	N	LSM	SE	SD	N	LSM	SE	SD
		..... kg				..... kg		
TBR[a]								
11	1,120	30.7	0.24	6.37	614	25.8	0.22	5.38
21	324	27.9	0.41	6.75	101	22.4	0.41	5.85
22	3,145	26.8	0.18	9.01	1,184	21.8	0.16	5.10
32	322	25.0	0.41	5.28	47	19.7	0.61	4.68
33	407	23.1	0.38	6.19	57	20.2	0.56	4.40
R^2 (%)				4.7				10.4
Significance		***		**		***		+
Sex								
Ewe	2,606	25.5	0.20	5.92	945	23.0	0.22	4.93
Ram	1,854	28.7	0.23	10.99	835	23.4	0.23	5.71
Wether	858	25.8	0.30	5.82	223	21.6	0.37	5.03
R^2				3.2				3.8
Significance		***		**		***		**
Dam age								
1	689	24.0	0.33	6.32	209	20.5	0.36	5.81
2	1,353	26.1	0.25	6.51	408	21.3	0.29	5.25
3	1,180	27.8	0.26	12.47	405	22.5	0.29	4.76
4	886	27.7	0.28	6.30	345	23.2	0.29	5.76
5	571	27.7	0.34	6.58	254	22.5	0.31	5.43
6	299	27.2	0.43	6.11	182	22.4	0.35	5.31
≥7	340	26.3	0.42	6.47	200	21.6	0.34	5.74
R^2 (%)				2.0				2.0
Significance		***		**		***		**

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.

*** = $P<.001$; ** = $P<.01$; + = $P<.10$

Within-breed multiplicative and additive correction factors for W60 by type of birth and rearing, sex of lamb and dam age are given in Table 6. Suffolk lambs born and raised as singles are 10% or 2.71 kg, 15% or 3.90 kg, 23% or 5.64 kg and 33% or 7.58 kg heavier than lambs born twins and raised as singles, born and raised as twins, born triplets and raised as twins and born and raised as triplets, respectively. Corresponding differences for the Dorsets are 15% or 3.39 kg, 19% or 4.07 kg, 31% or 6.08 kg and 28% or 5.62 kg, respectively. Suffolk ram lamb weights at 60-d are 13% or 3.21 kg and 12% or 2.97 kg heavier than those of ewe and wether lambs, respectively. For Dorsets, corresponding differences are 11% or 2.35 kg and 8% or 1.74 kg, respectively. Curvilinear effects of dam age on W60 were found in both breeds. In Suffolks, maximum W60 values were produced by 3-, 4-and 5-yr-old dams. In Dorsets, average W60 weights were largest in lambs produced by 4-yr-old dams.

Table 6. Within-breed multiplicative (MULT) and additive (ADD) adjustment factors for the effects of type of birth and rearing (TBR), Sex of lamb and dam age on 60-d weight

Variable	Breed			
	Suffolk		Dorset	
	MULT	ADD, kg	MULT	ADD, kg
TBR[a]				
11	0.87	-3.90	0.84	-4.07
21	0.96	-1.19	0.97	-0.68
22	1.00	0.00	1.00	0.00
32	1.07	1.74	1.10	.01
33	1.16	3.68	1.08	1.55
Sex				
Ewe	1.13	3.21	1.11	2.35
Ram	1.00	0.00	1.00	0.00
Wether	1.12	2.97	1.08	1.74
Dam age				
1	1.15	3.71	1.14	2.78
2	1.06	1.61	1.09	1.96
3	1.00	0.00	1.03	0.69
4	1.00	0.00	1.00	0.00
5	1.00	0.00	1.03	0.74
6	1.02	0.58	1.04	0.83
≥7	1.05	1.43	1.08	1.68

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.

Weight at 90-d (W90)

Results of the within-breed analyses of variance and mean squares for lamb age-adjusted 90-d weights (W90) showed that main effects (i.e. contemporary group, type of birth and rearing, sex of lambs and dam age) are highly significant ($P<0.001$) in both breeds with the single exception that Dorset dam age effects are significant at $P<0.01$. Among these main effects, using Suffolk data, contemporary group contributed the largest amount of W90 variation (31.4%) followed by lamb sex (7.2%), type of birth and rearing (6%) and dam age (1.9%). For Dorsets, contemporary group contributed the largest source of variation (17.9%) followed by type of birth and rearing (3.8%), sex of lambs (2%) and dam age (1%).

Within-breed W90 least squares means, standard errors and standard deviations by type of birth and rearing, lamb sex and dam age are given in Table 7. Variances among type of birth and rearing, lamb sex and dam age subclasses were heterogeneous ($P<0.01$) in both breeds except for Suffolk dam age subclasses which were nonsignificant ($P>0.10$). Multiplicative adjustments, then, are suggested for type of birth and rearing and lamb sex in both breeds. Multiplicative adjustments for dam age are suggested for Dorsets but for Suffolks, additive adjustment for dam age effects are indicated. Within-breed multiplicative and additive correction factors for the effects of type of birth and rearing, lamb sex and dam age on 90-d weight are given in Table 8. Weights at 90-d of Suffolk lambs born and raised as singles are 7% or 2.99 kg, 11% or 4.36 kg, 18% or 6.44 kg and 23% or 8.13 kg heavier than lambs born twins and raised as singles, born and raised as twins, born triplets and raised as twins, and born and raised as triplets, respectively. Corresponding differences for Dorsets are 12% or 3.55 kg, 16% or 5.02 kg, 17% or 5.43 kg and 17% or 5.35 kg, respectively. Weights at 90-d in Suffolk ram lambs were 13% or 4.84 kg and 11% or 4.15 kg heavier than those of ewe and wether lambs, respectively. For Dorsets, corresponding differences were 11% or 3.49 kg and 10% or 3.04 kg, respectively. Dam age effects on Suffolk 90-d weights were curvilinear with the heaviest average 90-d lambs being produced by 5-yr-old ewes. However, no significant ($P>0.05$) differences were observed in 90-d weights of lambs produced by 3-, 4-, and 5-yr-old dams. For Dorsets, dam age effects on 90-d weights were also curvilinear with the heaviest average 90-d lambs being produced by 3-yr old dams.

Table 7. Number of observations (N), least squares means (LSM), standard errors (SE), and standard deviations (SD) for age-adjusted 90-d weight by breed, type of birth and rearing (TBR), sex of lamb, and dam age (DA)

Variable	Breed							
	Suffolk				Dorset			
	N	LSM	SE	SD	N	LSM	SE	SD
		..... kg				..... kg		
TBR[a]								
11	512	42.0	0.33	8.53	522	36.4	0.57	16.64
21	125	39.0	0.59	9.74	92	32.9	1.09	6.18
22	1,195	37.6	0.25	7.97	923	31.4	0.47	6.07
32	153	35.5	0.55	7.37	61	31.0	1.40	6.44
33	135	33.9	0.59	7.34	33	31.1	1.83	6.23
R^2 (%)				6.0				3.8
Significance		***		**		***		**
Sex								
Ewe	1,087	35.8	0.28	7.01	786	31.3	0.61	13.76
Ram	817	40.6	0.31	9.01	693	34.7	0.64	6.92
Wether	216	36.5	0.52	8.39	152	31.7	1.10	5.61
R^2 (%)				7.2				2.0
Significance		***		**		***		**
Dam age								
1	266	34.4	0.50	9.12	154	30.6	1.06	7.09
2	499	37.3	0.39	7.94	413	32.3	0.77	6.85
3	438	38.7	0.39	8.12	335	34.5	0.80	20.18
4	341	38.7	0.42	8.29	265	33.4	0.80	6.54
5	237	38.8	0.48	7.97	167	33.1	0.99	5.95
6	159	38.1	0.56	8.19	123	32.6	1.06	6.55
≥7	180	37.0	0.53	7.88	174	31.4	0.90	7.01
R^2 (%)				1.9				1.0
Significance		***		NS		**		**

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.
*** = P.<001; ** = P<.01; NS = non significance.

Table 8. within-breed multiplicative (MULT) and additive (ADD) adjustment factors for the effects of type of birth and rearing (TBR), sex of lamb and dam age on 90-d weight

Variable	Breed			
	Suffolk		Dorset	
	MULT	ADD, kg	MULT	ADD, kg
TBR[a]				
11	0.90	-4.36	0.86	-5.02
21	0.96	-1.37	0.96	-1.47
22	1.00	0.00	1.00	0.00
32	1.06	2.08	1.01	0.41
33	1.11	3.77	1.01	0.33
Sex				
Ewe	1.13	4.84	1.11	3.49
Ram	1.00	0.00	1.00	0.00
Wether	1.11	4.15	1.10	3.04
Dam age				
1	1.13	4.40	1.13	3.96
2	1.04	1.47	1.07	2.24
3	1.00	0.00	1.00	0.00
4	1.00	0.00	1.03	1.11
5	1.00	0.00	1.04	.38
6	1.02	0.68	1.06	1.88
7	1.05	1.78	1.10	3.09

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.

Weight at 120-d (W120)

Within-breed analyses of variance and mean squares results for lamb age-adjusted 120-d weights (W120) showed that main effects (i.e. contemporary group, type of birth and rearing, sex of lambs and dam age) are significant ($P<0.001$) in both breeds with the exception that dam age effects only approached significance at $P<0.10$. Among these main effects, using Suffolk data, contemporary group contributed the largest amount of W120 variation (51.4%), followed by lamb sex (8.9%), type of birth and rearing (3.1%) and dam age (2.9%). For Dorsets, contemporary group, lamb sex, type of birth and rearing and dam age contributed 44.1, 6.3, 5.7, and 0.6%, respectively, to the total variation of W120. Dam age effects among Dorsets (0.6%) contributed considerably less to variation in W120 than among Suffolks (2.9%). This suggests that Dorset lambs become independent from the dam's milk supply at an earlier age than Suffolk lambs.

Least squares means, standard errors and standard deviations for lamb age-adjusted 120-d weight by breed, type of birth and rearing, lamb sex and dam age are given in Table 9. Heterogeneous ($P<0.01$) variances among type of birth and rearing, lamb sex and dam age subclasses were found using Suffolk data. Using Dorset data, heterogeneous ($P<0.01$) variances were found only among lamb sex subclasses. Variances among Dorset type of birth and rearing subclasses were nearly heterogeneous ($P<0.10$) but dam age subclasses were not heterogeneous ($P>0.10$). These results suggest that multiplicative adjustments for the effects of type of birth and rearing, lamb sex and dam age on W120 should be made on Suffolk data. However, for Dorsets, multiplicative adjustments are suggested for type of birth and rearing and lamb sex.

Table 9. Number of observations (N), least squares means (LSM), standard errors (SE), and standard deviations (SD) for age-adjusted 120-d weight by breed, type of birth and rearing (TBR), Sex of lamb, and dam age (DA)

Variable	Breed							
	Suffolk				Dorset			
	N	LSM	SE	SD	N	LSM	SE	SD
	..... kg				..... kg			
TBR[a]								
11	351	52.1	0.43	11.54	266	42.3	0.46	8.93
21	132	46.6	0.64	11.62	42	39.1	0.98	8.83
22	1,240	47.6	0.31	11.19	463	37.7	0.39	8.55
32	123	45.6	0.67	8.79	33	37.7	1.22	5.97
33	175	42.7	0.60	10.83	28	36.1	1.27	7.68
R^2 (%)				3.1				5.7
Significance		***		**		***		+
Sex								
Ewe	1,058	44.1	0.31	9.29	433	36.5	0.47	7.65
Ram	807	51.6	0.35	12.25	300	41.6	0.54	9.63
Wether	156	46.2	0.64	11.00	99	37.4	0.85	7.54
R^2 (%)				8.9				6.3
Significance		***		**		***		**
Dam age								
1	187	41.9	0.60	8.98	85	37.5	0.88	8.66
2	528	46.6	0.41	11.58	169	38.5	0.67	7.70
3	466	48.7	0.41	11.79	164	39.5	0.69	8.45
4	345	49.4	0.46	11.89	147	40.0	0.65	9.11
5	261	49.4	0.52	10.88	107	38.7	0.72	9.30
6	126	48.1	0.67	11.44	77	37.9	0.84	9.99
≥7	108	47.0	0.72	11.69	83	37.9	0.80	8.69
R^2 (%)				2.9				0.6
Significance		***		**		+		NS

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.

*** = P<.001; ** = P<.01; + = P<.10; NS = non significance.

Additive adjustments are indicated for dam age effects on 120-d weights of Dorset lambs.

Within-breed multiplicative and additive adjustment factors for the effects of type of birth and rearing, lamb sex and dam age on 120-d weight are presented in Table 10. Suffolk lambs born and raised as singles are 7.7% or 3.4 kg, 9.8% or 4.52 kg, 14.3% or 6.54 kg and 22% or 9.39 kg heavier than lambs born twins and raised as singles, born and raised as twins, born triplets and raised as twins, and born and raised as triplets, respectively. For Dorsets, corresponding differences are 7.9% or 3.20 kg, 12.3% or 4.60 kg, 12.3% or 4.54 kg and 16.8% or 6.2 kg, respectively. Suffolk ram lambs at 120-d of age were 17% or 7.44 kg and 12% or 5.32 kg heavier than ewe and wether lambs, respectively. Corresponding differences for Dorset lambs were 14% or 5.08 kg and 11% or 3.95 kg, respectively. Dam age effects on 120-d weight in Suffolk lambs were curvilinear with maximum average 120-d weights being produced by 5-yr-old dams. However, no significant (P > .05) differences were observed in 120-d lamb weights among progeny of 4- and 5-yr-old ewes. Among Dorset ewes, maximum 120-d lamb weights were produced by 4-yr-old dams.

Results show that among the environmental factors to be adjusted (birth type or type of birth and rearing, lamb sex and dam age), variances associated with birth type or type of birth and rearing subclasses were significantly (P<0.01) heterogeneous in Suffolks. However, for Dorsets, variances of birth type or type of birth and rearing were significantly (P<0.01) heterogeneous for weights at birth, 30-, and 90-d, and approached heterogeneity (P<0.10) for 60- and 120-d weights. Variances of lamb sex subclasses were mostly significantly (P<0.01) heterogeneous in both breeds.

Table 10. Within-breed multiplicative (MULT) and additive (ADD) adjustment factors for the effects of type of birth and rearing (TBR), sex of lamb and dam age on 120-d weight

Variable	Breed			
	Suffolk		Dorset	
	MULT	ADD, kg	MULT	ADD, kg
TBR[a]				
11	0.91	-4.52	0.89	-4.60
21	0.98	-1.04	0.96	-1.40
22	1.00	0.00	1.00	0.00
32	1.04	2.02	1.00	-0.06
33	1.11	4.87	1.04	1.60
Sex				
Ewe	1.17	7.44	1.14	5.08
Ram	1.00	0.00	1.00	0.00
Wether	1.12	5.32	1.11	3.95
Dam age				
1	1.18	7.48	1.07	2.48
2	1.06	2.77	1.04	1.41
3	1.01	0.71	1.01	0.50
4	1.00	0.00	1.00	0.00
5	1.00	0.00	1.03	1.29
6	1.03	1.34	1.05	2.02
≥ 7	1.05	2.39	1.06	2.09

[a] 11 = born and raised as singles; 21 = born as twins raised as singles; 22 = born and raised as twins; 32 = born as triplet raised as twins; 33 = born and raised as triplets.

Variances of dam age subclasses, except for 90-d weight, are heterogeneous ($P<0.05$) in Suffolks. However, for Dorsets, variances of dam age subclasses were only heterogeneous ($P<0.01$) for 60- and 90-d weights. These results suggest that for practical purposes, multiplicative adjustments are more suitable because most environmental factor variances were significantly heterogeneous. A combination of multiplicative adjustments for birth type or type of birth and rearing and lamb sex effects, and additive adjustments for dam age effects might be warranted.

Heterogeneous variances among type of birth and rearing, and lamb sex subclasses were also reported by EIKJE (1971) for spring weights (30- to 50-d of ages) and weaning weights (152- to 166-d of ages) of Norwegian sheep and by LEWIS *et al.* (1989) for 120-d weights of range Rambouillets. Both of these previous studies also reported that dam age subclass variances were not heterogeneous.

Most adjustment factors for birth types or types of birth and rearing, lamb sex, and dam age reported by previous studies (USDA, 1968; NOTTER *et al.*, 1975; MARTIN *et al.* (1980) were multiplicative. However, LEWIS *et al.* (1989) recommended a combination of multiplicative adjustments for types of birth and rearing and lamb sex effects, and additive adjustments for dam age effects for 120-d weights of range Rambouillets.

In general, effects of type of birth and rearing, and dam age on postnatal growth tend to decrease as lamb age increases from 30- to 120-d. This should be expected because increasing lamb age brings increasing independence from the maternal milk supply and, in the case of multiple-reared lambs, makes less important the effect of competition among sibs for a limited source of nutrients. The effects of lamb sex on postnatal growth increase from 30- to 120-d. These results show the necessity of determining and applying type of birth and rearing, dam age and lamb sex adjustment factors specific to the lamb postnatal age group concerned.

Differences between Suffolk and Dorset multiplicative and additive adjustment factors for BW, W_{30}, W_{60}, W_{90}, and W_{120} are significant, indicating that separate breed adjustment factors for these weight traits are needed.

CONCLUSIONS AND RECOMMENDATIONS

Results of the study suggested that for practical purposes, multiplicative adjustments of birth weight and the four postnatal weights for the effect of birth/rearing type, lamb sex, and dam age were more appropriate, because most environmental factor variances were significantly heterogenous.

Separate breed adjustment was needed for birth weight and the four postnatal weights, because differences in adjustment factors between breed.

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