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*J Anim Sci* 2000. 78:1132-1140.

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# Prewaning growth curves in Brown Swiss and Pirenaica calves with emphasis on individual variability<sup>1</sup>

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**ABSTRACT:** A quadratic polynomial model with random regression coefficients was used to describe preweaning growth curves of two beef cattle breeds widely used in the Spanish Pyrenees, according to genotype and season of birth effects. In addition, parameters of individual variability that can be used in a stochastic model were obtained. Data recorded indoors from birth to weaning of 217 Brown Swiss calves (3,509 observations) born either in spring or autumn (BS-S, BS-A) and 101 spring-born Pirenaica calves (PI-S, 967 observations) were analyzed. A quadratic model accurately fitted the preweaning weights ( $R^2 = .99$ ). Use of random regression coefficients improved the weaning weight adjustment; the residual variance of the model with intercept and linear random coefficients (9.61 kg<sup>2</sup>) was smaller than that of the model without them (130.03 kg<sup>2</sup>). Brown Swiss-S and PI-S calves had similar birth weight ( $40.9 \pm .96$  vs  $39.4 \pm .73$  kg), but BS-S calves

achieved significantly higher weaning weights at 150 d of age ( $175.2 \pm 2.45$  vs  $158.4 \pm 3.17$  kg). Prewaning growth patterns were different for each season of birth, but there were no differences in weaning weight at 150 d of age ( $172.9 \pm 2.01$  BS-A vs  $175.2 \pm 2.45$  BS-S). Standardization of weaning weights using a linear approximation could lead to biases, especially when comparing animals from the two calving seasons. The estimate of variances of random parameters should be done within breed and season of birth in order to take into account heteroscedasticity. The variances for BS-A, BS-S, and PI-S were 39.9, 57.6, and 32.2 kg<sup>2</sup> for the intercept, respectively, and .0159, .0141, and .0205 kg<sup>2</sup> for the linear coefficient. Covariance between the intercept and the linear coefficient (.34 kg<sup>2</sup>) was only statistically significant in the case of BS-S. The individual variance of weight at 150 d was 424.7 kg<sup>2</sup> and 526.7 kg<sup>2</sup> for BS-S and PI-S, respectively, almost 65% of the observed variance of weaning weight.

Key Words: Beef Cows, Breeds, Calving Season, Genetic Variation, Prewaning Period

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J. Anim. Sci. 2000. 78:1132–1140

## Introduction

Management in beef cattle production generally implies weaning at a fixed date so that calf age at weaning varies widely. Thus, an age-adjusted weaning weight is calculated, usually by means of a linear estimation of calf growth from birth to weaning (BIF, 1986). Although a linear adjustment is used (Gregory et al., 1978; Bolton et al., 1987; Boggess et al., 1991), the nonlinearity of calf growth can lead to bias in age-adjusted weaning weights (Brinks et al., 1962; Woodward et al., 1989). Frequently, only one or two weight records are available

per animal (birth and weaning weight) (Woodward et al., 1989; Rossi et al., 1992; MacNeil and Snelling, 1996), and growth patterns are estimated using a common covariate for the entire population.

The use of mixed models for the analysis of longitudinal data should provide a more accurate characterization of growth patterns because this methodology allows some parameters to be fixed and others to vary with animal, through random effects. Mixed models are a compromise between population models that do not take into account within-animal correlation and animal-specific models that could be overparametrized and are inadequate when data are unbalanced. Also, the separation of variation within individuals from variation between individuals for each of the parameters of the curve (Andersen and Pedersen, 1996; Littell et al., 1996) could be useful for stochastic models of growth. Simulations can be carried out using animals with different growth patterns instead of an average animal with the average parameters of the population (Werth et al., 1991; Davis et al., 1994).

<sup>1</sup>We wish to thank the farm staff working at La Garcipoliera research station. Research funded by the projects CE DG VI-8001 CT 90.0002, CE DG VI-1124, INTERREG II and INIA 94-72 and 98-44. Students in receipt of grants from INIA and the Basque government. Received April 5, 1999.

Accepted September 14, 1999.

The objective for this research was to estimate the preweaning growth curves of calves of two breeds widely used in the Pyrenees and the effect upon them of environmental factors, especially calving season and postpartum feeding level of their dams. Estimates of individual variability of the parameters describing the growth curve were also obtained.

## Materials and Methods

### Animals

The two suckler cattle breeds used in this analysis were Brown Swiss (**BS**) and Pirenaica (**PI**). Brown Swiss cattle (also known as *Parda Alpina* or *Bruna dels Pirineus*) were introduced in the Pyrenean area a century ago as a dual-purpose breed. Nowadays they are used exclusively as a suckler breed and not for dairy production, as in other areas. Pirenaica cattle have long been used in the Southern Pyrenees for beef production.

Data for this study were collected at La Garcipollera research station, in the mountain area of Central Pyrenees (Spain), from 1989 to 1997. The experimental site ranged in elevation from 950 to 2,200 m above sea level with an average annual precipitation of 999 mm.

Traditional management in the area consists of a winter housing period and a grazing season in which the cattle graze on high mountain ranges (1,500 to 2,200 m) during summer and on meadows and forest pastures during spring and autumn. Reproductive management involved part of the herd calving in the spring (March to May), which is typical of mountain areas, and the rest calving in the autumn (September to November), as an alternative management practice. The spring calving season included data from the two breeds (BS and PI), but only BS cows calved in the autumn.

Autumn-calving cows were housed immediately before calving, and the whole lactation occurred indoors. Calves did not receive any supplement until weaning at an average age of 137 d (ranging from 87 to 175). After weaning in March, cows grazed on valley and forest pastures during the spring and then on high mountain ranges in the summer.

Spring-calving cows were housed during the final third of pregnancy and remained indoors after calving through the first half of lactation (up to an average calf age of 110 d, ranging from 62 to 159 d). The second half of lactation occurred during the summer on high mountain ranges. The calves were weaned at 170 d of age (ranging from 82 to 214 d).

While the calves were indoors and following the typical management practiced in the Pyrenees, they were housed separated from the cows and only had access to their dams twice a day, so that they did not have access to the cows' feed. During the housing period, calves were weighed at weekly or fortnightly intervals from birth to weaning (autumn-born calves) or to turnout (spring-born calves), each animal having 9 to 19 weight records. Apart from calf weight data, other vari-

ables related to the calves or their dams were available: body condition score at calving (**BCS**), according to the 0 to 5 scale proposed by Lowman et al. (1976); **YEAR** in which data were recorded (1989 to 1997); calving season (**SEASON**), as spring or autumn; **PARITY** of the dam, defined as first or second vs third or more calving; calf sex (**SEX**); and postpartum feeding level of the dam (**PFL**), defined as High (more than 90 MJ ME/cow daily) vs Low (less than 90 MJ ME/cow).

The data set had 4,476 weights recorded indoors of 217 BS calves (127 autumn-born and 90 spring-born) and 101 PI spring-born calves (Table 1).

Weight at birth (**WB**), age (**A1**), and weight (**W1**) at the end of the housing period were always available, and spring-born calves also had records of age (**A2**) and weight (**W2**) at weaning at the end of the summer. Average daily gains during the housing period ( $ADG_i$ , indoors) were calculated as  $ADG_i = (W1 - WB)/A1$ , and gains of spring-born calves during the summer grazing period were calculated as  $ADG = (W2 - W1)/(A2 - A1)$ .

Milk yield (**MY**) was estimated for 118 BS animals by integrating 3 to 10 records per cow, measured by the weigh-suckle-weigh technique suggested by Le Neindre (1973).

### Statistical Analysis

Indoor data were analyzed with the MIXED procedure of SAS (Littell et al., 1996) using a linear model with random regression coefficients. Only interactions between breed and year and between season and year were significant in previous analysis of birth and weaning weights. Hence, the model included the interaction **YEAR** × **BREED** nested within **SEASON**, because data from Pirenaica calves were only registered in the spring. Weight of the animal *i* on day *d* ( $W_{i,d}$ ) was analyzed by the following model:

$$W_{i,d} = a_{SEX} + a_{PARITY} + a_{YEAR \times BREED(SEASON)} + A_i + (b_{SEX} + b_{PARITY} + b_{YEAR \times BREED(SEASON)} + b_{PFL} + B_i) \times d + c_{BREED(SEASON)} \times d^2 + e_{i,d} \quad [1]$$

where  $a_{SEX}$ ,  $a_{PARITY}$ , and  $a_{YEAR \times BREED(SEASON)}$  are the effects on the intercept of sex of calf, parity of dam, and interaction of year and breed nested in season, respectively;  $b_{SEX}$ ,  $b_{PARITY}$ ,  $b_{YEAR \times BREED(SEASON)}$ , and  $b_{PFL}$  are the effects on the linear coefficient of sex of calf, parity of dam, interaction of year and breed nested in season, and postpartum feeding level of dam, respectively; and  $c_{BREED(SEASON)}$  is the effect on the quadratic coefficient of breed nested in season.

In model [1] the random effects  $A_i$ ,  $B_i$  are multivariate normally distributed  $N(0, V)$ , and  $e_{i,d}$  are independent  $N(0, \sigma_e^2)$ . The matrix of variance and covariance  $V$  is a  $2 \times 2$  matrix because the model has two random coefficients ( $A_i$ ,  $B_i$ ). In order to take into account the heterogeneity of variance between breeds and seasons, the parameters were estimated within breed and season. Therefore,  $V$  is:

$$V = \begin{pmatrix} \sigma_{A_1}^2 & \sigma_{A_1B_1} & 0 & 0 & 0 & 0 \\ \sigma_{A_1B_1} & \sigma_{B_1}^2 & 0 & 0 & 0 & 0 \\ 0 & 0 & \sigma_{A_2}^2 & \sigma_{A_2B_2} & 0 & 0 \\ 0 & 0 & \sigma_{A_2B_2} & \sigma_{B_2}^2 & 0 & 0 \\ 0 & 0 & 0 & 0 & \sigma_{A_3}^2 & \sigma_{A_3B_3} \\ 0 & 0 & 0 & 0 & \sigma_{A_3B_3} & \sigma_{B_3}^2 \end{pmatrix} \quad [2]$$

where  $A_1$  ( $A_2$ ;  $A_3$ ) is the random intercept for autumn-born Brown Swiss calves (spring-born Brown Swiss calves; spring-born Pirenaica calves) and  $B_1$  ( $B_2$ ;  $B_3$ ) is the random slope for autumn-born Brown Swiss calves (spring-born Brown Swiss calves; spring-born Pirenaica calves).

The model assumes that the growth curve of each individual animal follows a second-degree polynomial. The quadratic coefficient was estimated within the BREED(SEASON) effect to take into account differences in growth due to breed or season. The intercept (a) and the linear coefficient (b) vary between individuals and are also influenced by the effects YEAR  $\times$  BREED(SEASON), SEX, PARITY, and PFL. The model, thus, separates variation within individuals, in terms of  $e_{i,d}$ , and from variation between individuals, in terms of ( $A_i$ ,  $B_i$ ).

The weight of an average animal at day d for the combination i of fixed effects was obtained from the solution of model [1]. Two types of errors were calculated: the standard error (SE) and the wide standard error. The SE is calculated from the (co)variance matrix of the estimated fixed effects ( $V_f$ ), as follows:

$$SE_i = \sqrt{(\mathbf{a}, \mathbf{b}, \mathbf{c}, \mathbf{d}^2)^T V_f (\mathbf{a}, \mathbf{b}, \mathbf{c}, \mathbf{d}^2)} \quad [3]$$

where  $\mathbf{a}$ ,  $\mathbf{b}$ , and  $\mathbf{c}$  are the vectors of fixed effects associated, respectively, to the intercept, linear, and quadratic coefficients.

**Table 1.** Description of the data set

Effect	Number of calves	Number of observations
Calving-Season		
Autumn	127	1,781
Spring	191	2,695
Breed		
Brown Swiss	217	3,509
Pirenaica	101	967
Postpartum feeding level		
High	185	2,450
Low	133	2,026
Parity		
1st and 2nd calving	195	2,751
$\geq$ 3rd calving	123	1,725
Sex		
Female	153	2,131
Male	165	2,345

The wide SE was derived from the following equation:

$$\text{Wide SE} = \sqrt{SE^2 + (1,d)^T V_{AB}(1,d) + \sigma_e^2} \quad [4]$$

where  $V_{AB}$  is a  $2 \times 2$  submatrix of  $V$  for each BREED and SEASON, where the unknown parameters have been replaced by their estimates. The standard error is used for comparing average curves, and the wide standard error is used for comparisons between individuals or between different records of an individual. A  $t$ -test was performed to compare weights at different ages. Significance of estimated animal covariances were obtained using the Wald test (SAS, 1992). In order to compare models with different covariance structures, a likelihood ratio test was used.

To analyze the relationship between growth indoors and growth at pasture in spring-born calves, correlations between ADGi, ADG, and MY were calculated.

### Results and Discussion

The environmental effects considered in this model can be grouped into two types. The first type are those affecting the intercept and related to calf weight on d 0 (weight at birth). The second type are those affecting the linear coefficient of the model and affecting weights from birth to weaning.

#### Weight at Birth

Weight at birth (**WB**) was significantly affected by PARITY, with calves born from first- or second-calving cows being  $3.13 \pm 1.15$  kg lighter at birth than those born from adult cows ( $P < .01$ , Table 2). This difference may be due to competition for nutrients between fetal and maternal growth in young cows (Holland and Odde, 1992). SEX was also a significant factor influencing the intercept of the model. Male calves were 6.4% heavier at birth than female calves.

The difference in WB between breeds was  $1.5 \pm 1.19$  kg; BS calves were heavier though not significantly (Table 3). Over a larger set of data, Casasús (1998) found a significant difference of 2.5 kg ( $P < .001$ ) between the WB of the two breeds. The average values obtained for the two breeds were similar to results reported by other authors: 44 kg for BS (Piedrafita et al., 1993) and 42.2 kg for PI calves (Altarriba et al., 1996).

Weight at birth was significantly higher in autumn-born than in spring-born BS calves. Body condition at calving was higher in autumn- than in spring-calving cows (+.2 points BCS); this reflects higher levels of feeding prior to calving provided by summer pastures as opposed to the restricted planes of nutrition offered to spring-calving cows during the winter. Undernutrition prior to calving can cause a decrease in fetal growth rates, and thus reduce WB (Spitzer et al., 1995), although some authors consider that only very acute underfeeding can impair calf WB (Agabriel and Petit, 1987).

**Table 2.** Least squares means (standard error) for weight (kg) at 0, 120, 150, and 180 d of age by calf sex (SEX), calving order of the dam (PARITY), and postpartum feeding level of the dam (PFL)

Effect	Calf age, d			
	0	120	150	180
SEX <sup>a</sup>				
Female	40.51 <sup>y</sup> ± .66	140.25 <sup>y</sup> ± 1.74	164.77 <sup>y</sup> ± 2.12	189.12 <sup>y</sup> ± 2.51
Male	43.29 <sup>z</sup> ± .57	147.73 <sup>z</sup> ± 1.49	173.42 <sup>z</sup> ± 1.80	198.95 <sup>z</sup> ± 2.14
PARITY <sup>a</sup>				
1st and 2nd calving	40.33 <sup>y</sup> ± .91	135.77 ± 2.39	159.21 <sup>y</sup> ± 2.90	182.48 <sup>y</sup> ± 3.43
≥ 3rd calving	43.46 <sup>z</sup> ± .56	152.22 <sup>z</sup> ± 1.47	178.99 <sup>z</sup> ± 1.78	205.59 <sup>z</sup> ± 2.12
PFL <sup>a</sup>				
Low	41.90 ± .49	133.89 <sup>y</sup> ± 2.26	156.47 <sup>y</sup> ± 2.80	178.88 <sup>y</sup> ± 3.35
High	41.90 ± .49	154.09 <sup>z</sup> ± 2.38	181.72 <sup>z</sup> ± 2.95	209.18 <sup>z</sup> ± 3.53

<sup>a</sup>Within a column, means lacking a common superscript differ ( $P < .05$ ).

*Birth to Weaning Weights*

Estimated weights at different ages for each level of SEX, PARITY, PFL, BREED, and SEASON are presented in Tables 2 and 3. The difference of weight between males and females, already observed at birth, was increased up to  $7.5 \pm 2.04$  kg ( $P < .01$ ) at 120 d of age and  $8.65 \pm 3.15$  kg ( $P < .01$ ) at d 150. The magnitude of the difference between sexes is smaller than observed by other authors working with the same breeds. In PI calves, male calves were heavier than female calves by 13 kg at 120 d of age (Altarriba et al., 1996) and 38 kg at 205 d of age (Varona et al., 1997). Piedrafita et al. (1993) observed that male BS calves were 21.7 kg heavier than females at 185 d of age.

Calves reared by first- or second-calving cows had lower gains than those reared by older cows. This difference in weight gains led to a difference of  $19.8 \pm 3.73$  kg in weight at d 150 of lactation ( $P < .01$ ). Piedrafita et al. (1993) found a difference of 34.3 kg in weight at

185 d of age of BS calves born from young and adult cows.

The feeding level that dams received after calving led to a difference of  $25.25 \pm 4.85$  kg on weight at 150 d of age, with those calves whose dams received a high PFL being heavier. The plane of nutrition of the cows is a major factor influencing calf growth rate, mainly if, as in this case, calves do not receive any supplement during lactation (Lowman et al., 1979; Sinclair et al., 1994; Casasús et al., 1997).

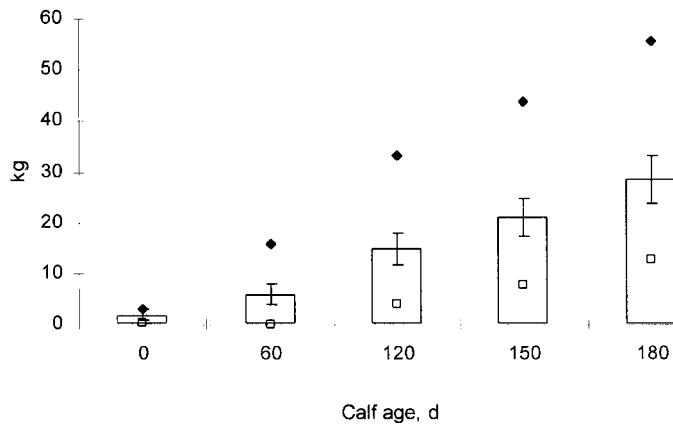
Although WB of the two breeds was not significantly different, the difference in weights increased up to  $20.6 \pm 3.86$  kg at 150 d of age ( $P < .001$ , Figure 1), with BS calves being heavier. The higher weights of BS calves can be attributed to the higher milk yield of their dams (Casasús, 1998). Milk consumption is the main trait affecting preweaning growth rates in beef cattle (Baker et al., 1976; Butson et al., 1980) and may also explain the PARITY (Lubritz et al., 1989) and PFL effects on calf weight. The effect of the milk yield of the dams on

**Table 3.** Least squares means of calf weights in each breed and calving season

	Calf age, d				
	0	60	120	150	180
Brown Swiss, autumn <sup>a</sup>					
Weight, kg	44.7	100.1	150.1	172.9	194.5
SE	.71	1.09	1.72	2.01	2.28
Wide SE	7.07	10.64	17.09	20.61	24.21
Brown Swiss, spring <sup>a</sup>					
Weight, kg	40.9	91.5	146.3	175.2	205.2
SE	.96	1.50	2.16	2.45	2.68
Wide SE	8.25	12.69	18.89	22.20	25.58
Pirenaica, spring <sup>a</sup>					
Weight, kg	39.4	86.0	131.9	158.4	177.2
SE	.73	1.29	2.36	3.17	3.87
Wide SE	6.51	11.08	18.82	22.95	27.18
Spring vs autumn	$-3.8^z \pm 1.13$	$-8.5^z \pm 1.75$	$-3.7 \pm 2.57$	$2.3 \pm 2.92$	$10.8^z \pm 3.19$
Brown Swiss vs Pirenaica	$1.5 \pm 1.19$	$5.6^z \pm 1.96$	$14.4^z \pm 3.17$	$20.6^z \pm 3.86$	$28.0^z \pm 4.65$

<sup>a</sup>SE standard error; Wide SE, see definition in text.

<sup>z</sup>Means significantly different from zero ( $P < .05$ ).



**Figure 1.** Mean (standard error) and within-year maximum (◆) and minimum (□) differences in weight between Brown Swiss and Pirenaica spring-born Brown Swiss calves.

calf growth traits is considered in breeding schemes by including maternal effects and permanent dam effects (Hohenboken, 1985), and PFL may be considered within the latter.

Estimates of weaning weight at 180 d of age (Table 3) are slightly lower than those presented by Piedrafita et al. (1993) in BS cattle and by Altarriba et al. (1996) in PI cattle. These differences may be due to the calves in the current study not receiving any supplement during lactation. This lack of supplementation, in our conditions, may have been the cause of the lower weaning weights and also of the narrower difference between males and females when compared with those reported by these authors.

Figure 1 shows the estimated average difference between breeds in weight of calves at various ages and the maximum and minimum differences observed among the years in this study. Although the magnitude of the difference between breeds was variable among years, BS calves were consistently heavier than PI calves.

Preweaning growth rate was clearly greater in Brown Swiss than in Pirenaica calves. However, other traits, such as postweaning growth rates or meat and carcass quality after fattening, must be considered when comparing the production efficiency of the two breeds (Alberti et al., 1998).

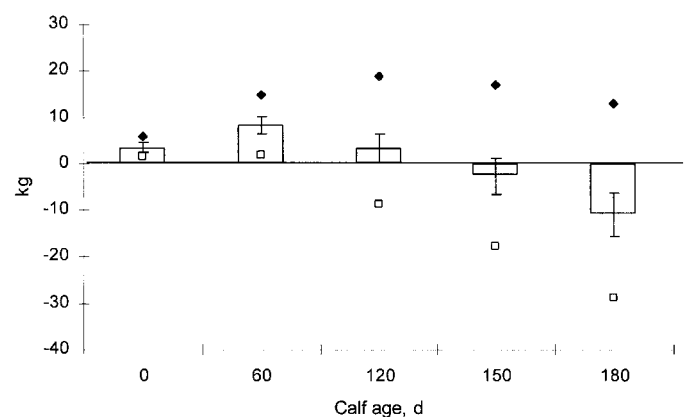
The difference in weight at birth between calving seasons increased up to  $8.5 \pm 1.75$  kg at 60 d of age ( $P < .01$ , Table 3), with autumn-born calves being heavier. Thereafter, the observed growth patterns led to nonsignificant differences at 120 and 150 d of age (Figure 2). The reverse tendency was observed at 180 d of age, when spring-born calves were  $10.8 \pm 3.19$  kg heavier ( $P < .001$ ). However, this latter comparison has to be regarded cautiously because 180 d of age was out of the actual range of ages of autumn-born calves.

The higher weights of autumn-born calves, in the current study only up to 130 d of age, have also been

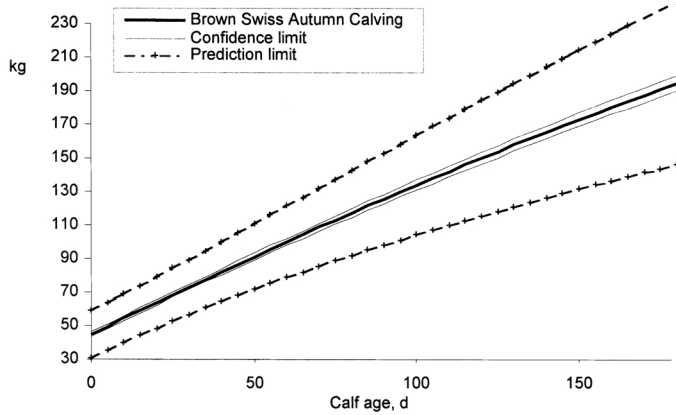
described by other authors in similar production systems. Asturiana de los Valles autumn-born calves were heavier at weaning than spring-born ones (Goyache, 1995). Piedrafita et al. (1993) found that BS autumn-born calves had higher growth rates than spring-born ones, and Osoro (1987) described the gains of autumn-born Rubia Gallega calves as 174 g/d higher than those of the spring-born.

The effect of calving season is related to management practices and to the feeding resources available for the animals throughout the year. In order to reduce production costs, feed restriction during the winter housing period in mountain conditions is commonly practiced. This restriction is applied during the last third of pregnancy of spring-calving cows and can cause a low level of body reserves at calving. The low BC at calving can affect reproductive rates (Wright et al., 1987) and also milk yield and, thus, calf gains. In contrast, autumn-calving cows accumulate sufficient body reserves during the summer grazing period. This increased body condition allows a certain degree of undernutrition during lactation because the mobilization of these reserves can supply enough energy for milk production, without impairing calf growth rates. In our conditions, the spring-calving season was advantageous in terms of calf weight from 140 d of age, probably due to the change of feeding management of dams and calves at turnout (see below). Extrapolating calf weight further than 160 to 170 d of age can be spurious. These ages are out of the range of data recorded during the housing period, and used to calculate the growth curves. Also, growth patterns on pasture do not necessarily continue the ones observed indoors.

Figure 2 shows the estimated average differences between calving seasons in weight of calves at various ages and the maximum and minimum differences observed among the years in this study. At 0 and 60 d autumn-born calves were as heavy or heavier than spring-born calves. However, at later ages this difference was not consistent across years. This variation



**Figure 2.** Mean (standard error) and within-year maximum (◆) and minimum (□) differences in weight between autumn- and spring-born Brown Swiss calves.



**Figure 3.** Growth curve of Brown Swiss, autumn-born calves. Average and confidence and prediction limits of estimates.

among years in preweaning growth performance may result from annual variation in weather and resulting differences in herbage production.

Early weaning would provide better performances for autumn-born calves, and weaning over 150 d of age would lead to higher weaning weights in spring-born ones. Nevertheless, the possible choice of one calving system or the other, or even both, must be analyzed with a wider scope, taking into account other goals, such as the management of the available natural resources.

*Linearity of Growth*

The quadratic coefficient, estimated within each breed and calving season, had a different sign for each calving season. The value obtained for the autumn,  $-7.5 \times 10^{-4}$  kg/d<sup>2</sup>, with lower daily gains at increasing calf age (Figure 3), could be explained by the decreasing of dams' milk production, the only source of nutrients for unsupplemented calves.

The value obtained for the spring,  $5.7 \times 10^{-4}$  kg/d<sup>2</sup>, implies higher growth rates at increasing calf age. This fact may be explained by the management of spring-calving cows, which by the second to third month of

lactation received a diet of a higher quality, as they grazed during part of the day on valley meadows, available from the end of the spring. This increase in feeding level may have increased milk yields (Coulon et al., 1986; Villalba et al., 1997; Casasús, 1998) and consequently calf gains.

Taking into account these results, the use of a linear approximation for the standardization of calf weight can lead to a certain degree of bias in the estimates. If the estimated quadratic curve is assumed to be correct in terms of calf age and weight and a linear approximation is used for estimating weight at 150 d of age using data from calves of 125 or 175 d of age, the estimation bias is  $\pm 1.2\%$  in spring-born calves and  $\pm 1.6\%$  in the autumn-born (Table 4). Although the magnitude of the biases is small (the SE of the estimated curve is between 1.14 and 1.47% of weight at 150 d), the different sign of the quadratic term in the two calving seasons leads to biases of different signs. At 150 d of age, the difference according to the estimated curve is  $2.3 \pm 2.92$  kg, with spring-born calves being heavier. Using data from young calves (125 d of age), the difference of standardized weights at 150 d is 2.6 kg, autumn-born calves being heavier, but using data from older calves (175 d of age) the difference of standardized weights at 150 d is 7.4 kg, spring-born calves being heavier.

The quadratic model fit accurately the preweaning weights in the calf age range studied ( $R^2 = .99$ ). The shape of the curve, and hence the sign of the quadratic term, depends on the interaction between potential calf growth and dam nutritional management. Due to this interaction, it could be useful to estimate the value of the quadratic term within homogeneous groups of animals, as Woodward et al. (1989) suggested. Nevertheless, the definition of those homogeneous groups is difficult and could explain the inconsistency observed in some studies (Rossi et al., 1992).

*Relationship Between Growth Rates Indoors and on Pasture*

Despite being older during the summer, growth rates of spring-born calves were significantly higher on high

**Table 4.** Biases of the estimates of weaning weight standardized at 150 d of age in spring- and autumn-born Brown Swiss calves

Item	Calf age at weaning, d			
	Spring		Autumn	
	125	175	125	175
W <sub>0</sub> , kg <sup>a</sup>		40.9		44.7
W <sub>d</sub> , kg <sup>b</sup>	151.0	200.1	153.9	190.4
LW <sub>150</sub> , kg <sup>c</sup>	173.1	177.4	175.7	170.0
W <sub>150</sub> , kg <sup>e</sup>		175.2		172.9
Bias, % <sup>f</sup>	-1.2	1.2	1.6	-1.6

<sup>a,b,e</sup>Weight at 0 d, and 150 d, respectively, obtained from the quadratic estimated curve.

<sup>c</sup>Linearly standardized weight at 150 d of age:  $LW_{150} = [(W_d - W_0)/d] \times 150 + W_0$ .

<sup>f</sup>Bias =  $(LW_{150} - W_{150})/W_{150} \times 100$ .

**Table 5.** Statistics of average daily gain indoors and on pasture, and milk yields observed in the Brown Swiss, spring-calving herd

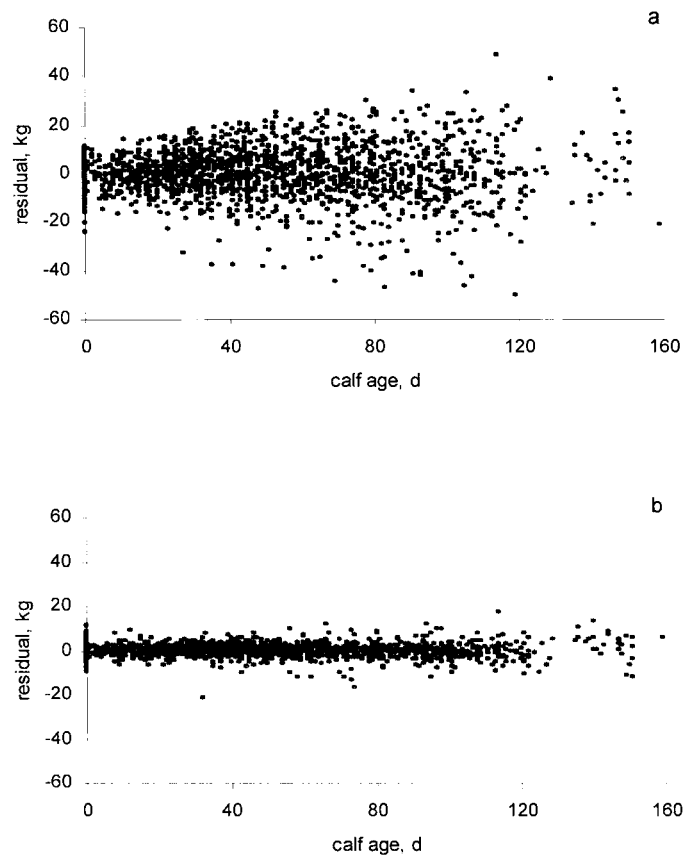
Trait	number	mean	SD
ADG indoors (0–110 d), kg	389	.80	.21
ADG pasture (110–170 d), kg	389	.93	.22
Milk yield, kg/d	118	7.48	1.93

mountain pastures than during the housing period (Table 5). The higher gains of calves on pasture can be due to the higher availability of nutrients for their dams, particularly at the start of the grazing season and if they had been undernourished during the housing period. Alternatively, the correlation between daily milk yield and calf ADG indoors was .71 (118 data,  $P < .01$ ), but between milk yield and calf ADG on pasture it was only .39 (118 data,  $P < .01$ ), reflecting a lower dependence of calf growth on milk production of the dam in this period. The increasing herbage intake of calves may compensate for the decrease in their dams' milk yield at advancing stages of lactation (Vicini et al., 1982). At 45 d of age, calves have been reported to obtain from pasture 2.4 times the energy they received from their dams' milk (Ansotegui et al., 1991).

The low relationship between ADG indoors and on pasture ( $r = .18$ ,  $P < .05$ ,  $n = 389$ ) would support the theory that gains on pasture depend mainly on calf growth potential, whereas gains during the housing period are related to the dam's milk potential.

#### Individual Variability

The variances of the random coefficients of the models, which reflect the individual variability in weight at birth (intercept) and growth rates (linear coefficient), are shown in Table 6. Both the variance of the intercept and that of the linear coefficient were significant; thus, they should be included in simulation models with stochastic component. Residuals of the models with and without the random coefficients are presented in Figure 4. The residuals increased with increasing age in the latter, and the model with random coefficients had uniformly distributed residuals. The residual variance was also reduced from 130.03 to 9.61  $\text{kg}^2$  when using random



**Figure 4.** Residuals of the models a) without and b) with random coefficients.

regression coefficients. The statistical model could have a quadratic random effect, but it was not included because the algorithm failed to converge properly. Nevertheless, the residuals were small in the model with only two random effects, even when age was high, which supports the exclusion of the quadratic random effect.

The variance of the linear coefficient was  $.014 \pm .0023 \text{ kg}^2$  for BS and  $.020 \pm .0031 \text{ kg}^2$  for PI spring-born calves, values that are similar to those described by Varona et al. (1997) for PI calves. Taking into account these values, the individual variance (derived from the wide SE) calculated at 150 d was 424.7 and 526.7  $\text{kg}^2$  for BS and PI, respectively, almost 65% of the variance of the weaning weights unadjusted for age.

**Table 6.** Variance and covariance of the random coefficients estimated in the model for each breed and calving season

Covariance	Breed	Season		
		Autumn	Spring	
		Brown Swiss	Brown Swiss	Pirenaica
Intercept		39.96 ± 5.5	57.62 ± 9.12	32.19 ± 5.19
Intercept-linear coefficient		.435 ± .0766	.339 ± .106	.0459 ± .091
Linear coefficient		.0159 ± .0021	.0141 ± .0023	.0205 ± .0031
Overall residual			9.61 ± .219	

In the case of BS calves, the variances of the intercept and the linear coefficient were similar in the two calving seasons, but the covariance between the two parameters was not significant in the autumn, but it was positive in the spring ( $r = .38$ ,  $P < .01$ ). In PI calves, the covariance was not significant either. The use of a model with 0 correlation in BS autumn-born calves and PI spring-born ones was not different from original model (LRT = .3;  $P = .86$ ). Therefore, the relationships between these parameters can vary between breeds and calving seasons.

The parameter estimates of individual variability are useful for simulating calf growth potential in a stochastic model. In deterministic simulations, each calf having the same environmental effects (season, breed, sex) will have the same mean growth curve. The stochastic simulation will add the animal effect to the mean curve. Each calf will have a different deviation value of the two parameters (intercept and linear coefficient), which will be obtained from a distribution with the estimated (co)variance parameters. It is necessary to estimate these (co)variance parameters within groups in order to take into account differences in variability of animals according to genotypes and environments, such as breed and season in this study.

If genealogy is available, a better dissection of individual variability should decompose the animal effect into its genetic and permanent environment components (Jamrozik et al., 1997; Varona et al., 1997). However, considering only the animal effect would be accurate enough for the purposes of most nongenetic simulations.

## Implications

A quadratic model fitted preweaning growth patterns, and adjustment for age at weaning with a linear approximation could lead to bias in weight estimates. However, only two random coefficients (intercept and linear) allowed for the representation of the individual variability in weight. Estimates of environmental effects on growth curves and of individual variation of parameters could be used for the modeling of preweaning calf performance in simulations of management alternatives in Pyrenean suckler cattle farms.

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