Different Commercial Broiler Crosses Have Different Susceptibilities to Leg Weakness[1]

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ABSTRACT A trial was conducted to investigate the susceptibility of different genotypes of broilers to leg weakness. Four crosses of commercial broiler lines were assessed. Birds were reared on commercial diets at commercial stocking densities. Indices of leg weakness examined included: walking ability, tibial dyschondroplasia (TD), foot pad burn, hock burn, and angulation of the hock joint. Body weight and feed efficiency were also measured. There were small differences in BW and feed efficiency among the commercial crosses; however, there were large differences in some of the indices of leg weakness among the crosses. Three crosses had similar prevalence of TD; one cross had much less TD than the others. There were large differences in walking ability among crosses. There were also differences among crosses in the prevalence of foot pad and hock burn and angulation of the hock joint. Adjusting the observations for differences in BW did not substantially alter the findings. There were differences among genotypes regarding the correlation coefficients between walking ability and BW, walking ability and hock burn, and TD and BW. It was concluded that there were large differences in some important traits associated with leg weakness among the commercial line crosses.

(*Key words*: leg problems, tibial dyschondroplasia, commercial line cross broilers, feed efficiency, body weight)

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INTRODUCTION

Several studies have recently reported the effect of husbandry practices on leg weakness in broilers (Sørensen *et al.*, 1999; Su *et al.*, unpublished data). In these studies, methodologies for measuring factors contributing to walking ability were developed and validated. These measures proved robust and sensitive, allowing differences in the prevalence of leg weakness between populations to be determined with some precision. Furthermore, it was proven possible to correct the observations for differences in BW, allowing absolute changes in walking ability and indices of skeletal abnormality to be measured, independent of differences in BW. In these studies, relatively minor improvements in leg weakness were achieved, even by quite severe manipulations of husbandry, but there were indications that there was a strong genetic component to the expression of leg weakness. In turkeys, Emmerson *et al.* (1991) showed only modest differences in walking ability between lines selected for different leg characteristics. However, in subsequent studies, Ye *et al.* (1997) and Nestor and Anderson (1998) have shown that a relatively unimproved line, exhibiting good leg structure and walking ability, can be used to improve walking ability in subsequent crosses, but that the penalty in terms of reduced BW and breast width was large.

A large proportion of the leg weakness seen in commercial broiler chickens is related to the rapid juvenile growth rate (Wise, 1975; Hartmann and Flock, 1979). It has become clear that, although many of the components causing leg disorders can be exacerbated by malnutrition, leg weakness can still be an important economic and welfare problem even when supplying all necessary nutrients (Poulos *et al.*, 1978). There is evidence that differences in walking ability exist between crosses of commercial broiler lines that otherwise perform equally (Kestin *et al.*, 1992). Although there is a strong correlation between leg weakness and growth rate (Sørensen *et al.*, 1999; Su *et al.*, unpublished data), it has long been realized that progress can be made in reducing and eliminating leg disorders by genetic means. Haye and Simons (1978) found that the fastest

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Abbreviation Key: FCR = feed conversion ratio; GS = gait score; GSA = gait score excluding score 4 and 5; RGR = relative growth rate; TC = tibial curvature; TD = tibial dyschondroplasia.

TABLE 1. Summary of experimental treatment details

Cross	Replicates per cross	Birds per replicate	Birds assessed per cross	Density	Feeder space
				(birds / m^2)	(cm / bird)
1	22	30	618	18	4
2	26	30	749	18	4
3	24	30	646	18	4
4	24	30	673	18	4

growing line of broilers out of five had the lowest incidence of twisted legs; however, several workers have found a poor correlation between growth characteristics and specific leg abnormalities in poultry (Wongvalle *et al.*, 1993; Zhang *et al.*, 1995; Kuhlers and McDaniel, 1996). Further, several genetic experiments have shown that many of the components contributing to leg disorders have a moderate heritability (Riddell, 1976; Sheridan *et al.*, 1978; Leenstra *et al.*, 1984; Mercer and Hill, 1984). In a review, Sørensen (1992) concluded that the genetic correlation between growth rate and incidence of leg disorders was positive but not to a degree that ruled out the possibility of improving growth rate and decreasing the incidence of leg disorders simultaneously.

Because leg weakness remains an important welfare and production issue, a trial was undertaken to examine differences in the susceptibility to leg weakness among different genotypes of broiler. The prevalence of indices of leg weakness, and their correlation with production characteristics, was examined and related to production characteristics in four crosses of commercial broiler lines available in Europe.

MATERIALS AND METHODS

Experimental Methods

Bird husbandry was as described in Sørensen *et al.* (1999) unless otherwise stated. One thousand eggs per line cross were obtained from commercial hatcheries and, after fumigation, incubated at the laboratory. On the day of hatch, chicks were sexed and tagged and placed, at random but balanced for sex, in rearing pens. A photoperiod of 21 h was provided with a light intensity of approximately 15 lx at bird height with less than 0.3 lx during the scotoperiod. Thirty minutes dusk (approximately 4 lx) was provided towards the end of the photoperiod. Birds were fed a broiler starter ration from hatching to 14 d of age (ME = 3,100 kcal / kg, 21.8% protein) and broiler grower ration (ME = 3,150 kcal / kg, 20.2% protein) thereafter. The starter diet contained a coccidiostat. Water was available for *ad libitum* consumption from nipple drinkers. A summary of number of birds used, density, and feeder space per bird is given in Table 1.

Assessment of Traits

The principle indices of leg weakness adopted, walking ability (GS) and TD, were assessed in all birds according to the methods of Kestin *et al.* (1992) and Ducro and Sørensen (1992), respectively. Tibial dyschondroplasia was assessed at 28 d of age while the birds were housed in the trial pens. The left leg of each bird was assessed using a low intensity x-ray fluorescence device[3] as described by Bartels *et al.* (1989). The size of the cartilage plug present was scored on a scale from 0 to 3. Score 0 was given for no occurrence of TD and 3 for cases where the cartilage almost filled the proximal head of the tibio-tarsus (Edwards and Veltmann, 1983). A longitudinal section of the proximal end of tibia, shown in Figure 1 illustrates the four categories. When viewed by the Lixiscope, the distinction between score 0 and 1 was difficult. Simultaneously, TC was also assessed by the Lixiscope and scored on a scale from 0 to 3 with 0 representing no curvature, and 3 severe curvature of the proximal part of the tibia. As the replicate pens were too small to allow adequate observation of walking ability, 24 h before assessment of GS at 35 d of age, all pen divisions were removed, allowing birds from all treatments to mix so that birds could be assessed at random and blind to treatment. Birds were gait scored individually by an experienced assessor who assessed the walking ability of the birds when moving spontaneously in the rearing

FIGURE 1. Longitudinal sections of the proximal end of tibia in relation to the four categories of tibial dyschondroplasia (TD) (score 0, 1, 2, and 3 from left to right).

[3]Lixiscope, Lixi Inc., Downers Grove, IL 60515.

TABLE 2. Least squares means and SD for leg weakness traits

Trait[1]	Cross 1	Cross 2	Cross 3	Cross 4	SD[3]
TD	0.133[a]	0.137[a]	0.088[b]	0.147[a]	0.367
TC	0.150[b]	0.137[b]	0.183[b]	0.315[a]	0.453
GS	1.488[c]	1.430[c]	1.975[a]	1.776[b]	0.840
GSA	1.488[c]	1.416[c]	1.939[a]	1.744[b]	0.813
Foot	0.620[bc]	0.645[b]	0.799[a]	0.565[c]	0.621
Hock	0.531[b]	0.452[c]	0.679[a]	0.486[bc]	0.564
Angul	0.129[b]	0.109[b]	0.247[a]	0.262[a]	0.447
GS 4 and 5, %[2]	0[b]	0.14[b]	1.43[a]	1.23[a]	

[a–c]Estimates in a row with no common superscript differ significantly ($P < 0.05$).

[1]TD = tibial dyschondroplasia; TC = tibial curvature; GS = gait score; GSA = GS excluding score 4 and 5; Foot = foot pad burn; Hock = hock burn; Angul = valgus or varus angulation.

[2]This row is the percentage of birds with gait score 4 or 5.

[3]Estimated by eliminating the effects of cross, sex, and block.

environment, assigning the bird a score from 0 for a perfectly normal bird to 5 for a bird that could not walk at all.

At assessment of TD and GS, the birds were individually weighed. Feed consumption from 1 to 30 d of age and BW at 21 and 30 d of age was recorded on a pen basis, so that FCR and RGR could be calculated. In addition, carcasses were assessed for prevalence of foot pad burn, hock burn, and valgus or varus angulation postmortem. As the carcasses passed on the evisceration line, the foot pads and hocks of each bird were evaluated and a combined score for both legs given from 0 to 3, with 0 for no sign of damage and 3 for extended burn and inflammation. Simultaneously, the valgus or varus angulation was subjectively evaluated and scored on a scale from 0 to 3 with 0 for no angulation of the hock (less than 5 degrees) and 3 for severe angulation (greater than 40 degrees). In total, 2,687 birds were assessed. Ross 208 broilers (Cross 1) were compared with Ross 308 broilers (Cross 2), Cobb 500 broilers (Cross 3), and Shaver broilers (Cross 4).

Statistical Analysis

The data for the traits measured were analyzed by an ANOVA model with a factorial arrangement of line cross, block, and sex, with pen nested within the combination of cross and block. In a second model, BW at the time of measurement was used as covariable for analyses of leg weakness traits. For pen-based variables, the model included cross and block only. In order to examine the effect of BW on TD and GS in detail, a regression analysis was conducted using a simple regression model. Spearman's rank-order correlations were also calculated for each cross.

Because previous studies have indicated that many of the birds with a GS of 4 or 5 have infections in their joints or bones (Kestin *et al.*, 1992), the GS data were also analyzed with these birds excluded from the data set. These data are presented in the tables as gait score excluding 4 and 5 (GSA). The ANOVA and the regression analyses, as well as the calculation of least squares means, were conducted by using the GLM procedure of SAS® (SAS Institute, 1994).

RESULTS

The least squares means for the leg weakness traits measured are shown in Table 2. The prevalence of TD in the crosses was similar, with the exception of Cross 3, which had much lower TD than the other crosses. Curvature of the tibia was also similar in three of the crosses, but with Cross 4 having more curved tibias. There were large and significant differences in GS among crosses, with Crosses 1 and 2 having the best GS, and Cross 3 the worst. There were significant differences in the proportion of birds scored 4 and 5 among crosses, with Crosses 1 and 2 having a lower proportion, and Crosses 3 and 4 a higher proportion. Adjusting the data set to remove the birds with a GS of 4 or 5 did not change the main findings relating to GS. Crosses 1 and 2 still had the best walking ability, and Cross 3 the worst. There were also differences among crosses in the prevalence of foot pad and hock burn and angulation of the hock joint. Crosses 1 and 4 had low foot pad burn scores, and Cross 3 had the highest. Cross 2 had the lowest hock burn scores and Cross 3 the highest. Crosses 1 and 2 had the lowest angulation scores, and Crosses 3 and 4 the highest.

Adjusting the observations for differences in BW did not substantially alter the findings (Table 3). Only the orders of hock burn scores changed, with Crosses 1, 2 and 4 having similar scores, and Cross 3 having higher scores.

The least squares means for the growth and efficiency of the different crosses are shown in Table 4. There were small but significant differences in BW at 28 and 35 d of age among the crosses studied, with Crosses 1 and 4 achieving the highest weight at 35 d, and Cross 2 the lowest. Cross 3 had a significantly lower RGR during the latter part of the production cycle and Cross 4 had a higher FCR than Crosses 1 or 3.

TABLE 3. Least squares means for leg weakness traits corrected for live weight

Trait[1]	Cross 1	Cross 2	Cross 3	Cross 4
TD	0.129[a]	0.147[a]	0.086[b]	0.142[a]
TC	0.144[b]	0.153[b]	0.179[b]	0.308[a]
GS	1.455[c]	1.506[c]	1.964[a]	1.722[b]
GSA	1.452[c]	1.514[c]	1.922[a]	1.681[b]
Foot	0.615[bc]	0.662[b]	0.801[a]	0.555[c]
Hock	0.511[b]	0.489[b]	0.680[a]	0.455[b]
Ang.	0.128[b]	0.112[b]	0.244[a]	0.259[a]

[a–c]Estimates in a row with no common superscript differ significantly ($P < 0.05$).

[1]TD = tibial dyschondroplasia; TC = tibial curvature; GS = gait score; GSA = GS excluding score 4 and 5.

The Spearman's rank-order correlation coefficients for the main traits measured are given in Table 5. Most of the correlation coefficients were significantly different from zero. The largest correlation was found between GS and BW. Positive correlations were also found between GS and hock burn, and TD and BW. Other correlations, although significant, were weak. Although no significance test was conducted to compare cross differences, the correlation coefficients appeared to be different among crosses.

The linear regression coefficients for the main variables measured are shown in Table 6. The regression coefficients for TD on BW were small but significant, with significant differences in intercepts and regression coefficients being found among crosses. The regression coefficients for GS on BW were much higher for all crosses. Crosses 1 and 2 had a significantly lower intercept than Crosses 3 and 4, but Crosses 1 and 2 also had the steepest regression line, with Cross 3 having the flattest regression line. The findings remained substantially the same if the data set was adjusted to remove birds with a score of 4 and 5.

DISCUSSION

The main purpose of this trial was to evaluate the prevalence of leg weakness in different genotypes of broiler. However, the opportunity was also taken to measure growth and efficiency so that differences in the leg weakness traits measured could be related to performance.

The main findings were that Crosses 1 and 2 were similar and tended to have the lowest scores for indices of leg weakness, whereas Cross 3 tended to have the highest scores and Cross 4 tended to have more misshapen bones and legs.

Cross 3 had significantly less TD than the other three crosses. This may reflect differences in the selection pressure exerted on this trait by the company concerned. It was expected that TC would be strongly associated with TD (Wise, 1975; Nairn and Watson, 1972); however, in this study this was not the case. Cross 3, which had the lowest prevalence of TD, did not have a particularly low TC score, and Cross 4, which had an average TD score, had an exceptionally high TC score. Why the tibias are more curved in some crosses and not in others is not known. The curvature could reflect genetic differences in skeletal form, or could be a function of bone remodeling and reflect increased skeletal plasticity as the bird grows. The small correlation between TD and TC confirms that these factors are not closely linked. It may reflect that other elements of growth disturbance have played a role earlier in life, or that TD had occurred but disappeared by the age of measurement.

The differences among crosses in GS were large. In similar previous studies in which the effect of husbandry changes on walking ability were investigated (Sørensen *et al.*, 1999; Su *et al.*, unpublished data), the largest difference in GS that was achieved (corrected for differences in BW changes) was a highly significant 0.240 gait score units. The BW penalty for this improvement was 109 g. In the current study, there was

TABLE 4. Least squares means for growth traits and feed conversion ratio

Trait[1]	Cross 1	Cross 2	Cross 3	Cross 4
28-d BW	1,261[a]	1,196[b]	1,254[a]	1,265[a]
35-d BW	1,671[ab]	1,593[c]	1,655[b]	1,684[a]
Gain, 21 to 30 d	596.1[a]	566.1[b]	594.6[a]	602.1[a]
RGR, 21 to 30 d	57.88[a]	57.57[a]	58.30[a]	58.31[a]
Gain, 28 to 35 d	413.3[ab]	397.1[c]	405.8[bc]	418.4[a]
RGR, 28 to 35 d	28.20[ab]	28.42[a]	27.87[b]	28.28[ab]
FCR, 0 to 30 d	1.406[b]	1.419[ab]	1.408[b]	1.434[a]

[a–c]Estimates in a row with no common superscript differ significantly ($P < 0.05$).

[1]RGR = relative growth rate; FCR = feed conversion ratio.

TABLE 5. Simple correlations between traits measured

Cross	TD:[1] BW28[2]	TD:[1] GS[3]	TD:[1] GSA[5]	GS:[2] BW35[4]	GSA:[5] BW35	GSA:[5] Foot	GSA:[5] Hock	GSA:[5] Ang.[6]	TC:[7] BW28	Ang.: BW35	TC: Ang.	TC: TD
1	0.180**	0.151**	0.151**	0.531**	0.531**	0.083	0.305**	0.018	0.152**	0.015	0.057	–0.082
2	0.125**	0.102**	0.105**	0.493**	0.507**	0.025	0.194**	–0.004	0.159**	–0.003	–0.023	0.048
3	0.116**	0.050	0.042	0.350**	0.428**	0.094*	0.267**	0.092*	0.091*	0.062	0.063	0.009
4	0.188**	0.193**	0.168**	0.382**	0.474**	0.064	0.293**	0.179**	0.178**	0.187**	0.112**	0.111**

[1]TD = Tibial dyschondroplasia.

[2]BW28 = 28-d BW.

[3]GS = Gait score.

[4]BW35 = 35-d BW.

[5]GSA = Gait score, excluding scores 4 and 5.

[6]Ang. = Hock angle.

[7]TC = tibial curvature.

*$P < 0.05$.

**$P < 0.01$.

a difference of 0.509 GS units between Cross 1 and cross 3, with no difference in BW. If birds were grown to an average target GS of 1.455, birds of Cross 3 would be considerably lighter than birds of Cross 1. The differences in GS between lines would suggest that genetic improvements in GS can be achieved (Sørensen, 1992), but that very careful selection is required if an excessive penalty in weight gain is not to be paid (Nestor, 1998). Birds from Crosses 1 and 2 come from the same company and had similar scores for all traits measured. This result probably reflects similar selection pressure against leg defects or shared parentage.

The differences among crosses in the prevalence of foot pad and hock burn and angulation of the hock joint were interesting. Foot pad and hock burns are generally believed to be painful, and, as would be predicted, have positive correlations with GS. This study suggests that these conditions are not merely a function of poor management, but that there are real differences in the propensity of different crosses of broiler to develop these disorders, and that positive selection against these traits is possible. Similarly, the differences in angulation and TC scores would also suggest that it is possible to manipulate skeletal form by selection. It is interesting that the two crosses with high angulation scores (Crosses 3 and 4) also had the highest TC scores but the correlation between these traits was only significant in Cross 4.

The small but significant differences in BW measured at 28 and 35 d of age among the crosses studied could be important commercially. The differences in FCR among crosses were also small. Much larger differences have been generated by husbandry manipulations (Su *et al.*, unpublished data).

In this and previous studies (Sørensen *et al.*, 1999; Su *et al.*, unpublished data), the relationship between BW and GS was examined using linear regression models. These models have proved to be useful for identifying differences between treatments in more detail, especially when birds with a GS of 4 or 5 are removed; however, elsewhere it is reported that the relationship between GS and BW for a flock as a whole is nonlinear (Kestin *et al.*, 1992; Sørensen *et al.*, 1999). Birds with a GS of 4 or 5 tend to be light because they cannot compete for feed and water and thus upset the relationship. The low relative growth seen in birds in Cross 3 towards the end of the production cycle may indicate that their growth is being limited by their inability to compete due to deteriorating walking ability. Further work is required to confirm this conclusion.

In the present study, the differences between crosses in most of the leg weakness traits measured were large, and, adjusting the observations to the same BW, did not change the findings. However, in previous studies in which differences have been small, adjustment has been necessary to identify the differences between treatments (Sørensen *et al.*, 1999; Su *et al.*, unpublished data).

As mentioned above, leg weakness is thought to be related to the high juvenile growth rate of broilers

TABLE 6. Linear regressions of TD, GS, and GSA on body weight[1]

Trait	Cross	Intercept	Regression coefficient	R square
TD	1	–0.317**ab	0.358**ab	0.033
	2	–0.185b	0.269**b	0.016
	3	–0.169b	0.206**b	0.013
	4	–0.517**a	0.525**a	0.035
GS	1	–1.919**a	2.038**a	0.281
	2	–1.742**a	1.986**ab	0.243
	3	–0.290b	1.368**c	0.122
	4	–0.954**b	1.620**bc	0.146
GSA	1	–1.742**a	2.038**a	0.281
	2	–1.801**a	2.020**a	0.257
	3	–0.711**b	1.597**b	0.183
	4	–1.480**a	1.909**a	0.225

[a–c]Estimates in a column for each trait with no common superscript differ significantly ($P < 0.05$).

[1]Abbreviations for traits: TD = tibial dyschondroplasia; GS = gait score; GSA = gait score excluding score 4 and 5.

**$P < 0.01$.

(Wise, 1975; Hartmann and Flock, 1979). This and previous studies (Sørensen *et al*., 1999; Su *et al*., unpublished data) have indicated the strong positive correlation between BW and GS. There is evidence from these studies that poultry breeders have succeeded in reducing some factors, such as TD, that contribute to leg weakness. However, there is concern that many of the factors contributing to leg weakness are poorly understood and thus difficult to select against.

In a recent review, Hardiman (1996) indicated that selection against leg disorders was ranked 9th out of 12 factors by broiler breeders, with improved growth rate and feed efficiency being first and second, respectively. Hardiman (1996) indicated that broiler breeders predict an improvement in broiler growth rate of 600 g to 40 d of age over the next 10 yr. This is quite probable, as the next 5 yr of genetic improvement are already in the multiplication chain. From recent studies of the regression of GS on BW (Sørensen *et al*., 1999; Su *et al*., unpublished data), an increase in growth rate of this order would mean a deterioration in walking ability of approximately 1.1 units of GS, assuming that the genetic correlation is consistent with the phenotypic correlation, and that no active selection to improve walking ability is undertaken. If leg disorders continue to rank 9th out of 12 in the selection programs of the major broiler breeding companies, the prevalence of leg disorders and poor walking ability is likely to at best remain static, and may get worse.

In conclusion, the main purpose of this trial was to examine differences in leg weakness among commercial broiler crosses. Large differences in GS and other indices of leg weakness were found among the four crosses. When adjusted for BW differences, Crosses 1 and 2 were similar and tended to have the lowest scores for indices of leg weakness and Cross 3 tended to have the highest scores for indices of leg weakness. Cross 4 tended to have more misshapen bones and legs but was intermediate in terms of indices of leg weakness.

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