Selection for Growth and Feed Efficiency in Broiler: Realized Heritability and Responses of Selection

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ABSTRACT

The trait of body weight at a fixed age under *ad libitum* feeding is becoming less attractive due to accumulating negative impact of traits correlated to body weight. The correlation between weight gain and fat deposition is low but positive. The main goal of this study was to estimate genetic parameters, realized heritability and responses of selection. Data consisted of two selection lines in broiler, namely body weight (BW) and feed conversion ratio (FCR) lines. Estimation of genetic parameter was calculated by ASREML procedures based on animal model. Estimation of heritability was calculated through the regression of phenotypic means on cumulatively differential selection. Responses of selection were estimated by using average breeding value at each generation. Estimated heritability for body weight was 0.42 for BW line and 0.59 for FCR line, respectively. Estimated heritability for feed conversion was 0.44. However, there was an inconsistency between estimated and realized heritabilities. All traits measured had small-realized heritability, even they were negative for body weight and feed conversion in FCR line. The realized heritability for body weight in BW line was 0.10, while those for body weight and feed conversion in FCR line were -0.14 and 0.03. Genetic correlation between body weight and feed conversion ratio was 0.18, whereas phenotypic correlation showed no difference to 0.

Key words: *genetic parameters, realized heritability, body weight, feed conversion ratio*

INTRODUCTION

During the past decades, major emphasis have been paid in selection programs for broiler to body weight and rate of gain (Chambers et al., 1981). However, the trait body weight at a fixed age with *ad libitum* feeding, is becoming less attractive due to the accumulatting negative impact of traits correlated to body weight. The correlation between weight-gain and fat deposition is low, but positive (Leenstra, 1987). The increasing amount of fat is one of the pronounced negative consequences of selection for body weight. Alternative selection characteristics might be feed conversion. The genetic correlation between feed conversion and percentage abdominal fat is favourable (Leenstra, 1987). Therefore, feed conversion can be used to select a leaner broiler, or sib selection for a low percentage of abdominal fat improves feed conversion (Pym and Solvyns, 1979; Leenstra, 1987).

Genetic parameters such as heritabilities and genetic or phenotypic correlation can be estimated by realized heritability or variance component using animal model. Many studies concerning this have been conducted for broiler population. For instance, Liu *et al.* (1994) revealed that realized heritability of 8 week body weight ranged from 0.22 to 0.28 for a high weight line and from 0.23 to 0.28 for a low weight line. Su *et al.* (1997) estimated heritability of body weight using animal model were of 0.25 (REML method) and 0.26 (Bayesian analysis), respectively. Heritability estimates of feed consumption and efficiency at constant age as summarized by Pym (1990) ranged from 0.2 to 0.8 and averaged at 0.45 for feed consumption; estimates for feed efficiency ranged from 0.18 to 0.56, and the average was 0.25. Khan (1976) reported a genetic correlation between 8 and 30 week body weight of 0.86 ± 0.27 for normal and 0.15 ± 0.26 for dwarf broilers.

Although genetic aspect of both body weight and feed conversion has been studied intensively, additional research is still needed. For decicion about an optimal selection program in broiler production, ample information is required on the heritability of body weight and of feed conversion.

The aims of this study were to estimate the genetic parameters and responses of selection of body weight and feed conversion in broiler selection lines which are selected for growth rate (BW) and for feed conversion ratio (FCR).

MATERIALS AND METHODS

Animals

Animals originated from a line selected for growth and a line selected for feed conversion. Selection was performed every year in non-overlapping generation. In both lines, parents were selected on the basis of their own performance for body weight or feed conversion ratio. Within generation, two hatches were obtained with a maximum of 4 weeks between the youngest and oldest hatch. Random mating of the parent was used; the only restriction was the exclusion of matings between full and (or) half-sibs. At each generation, within line and hatch, 38 to 45 males and 106 to 130 females become candidates as sires and dams. Number of progeny per family used in this experiment ranged between 7 to 10 for BW line and 3 to 5 for FCR line.

Rearing

At hatching birds were sexed and wingbanded. Per hatch the males and females have been reared separately on litter in a pen according to standard broiler procedures from day old chicken until 21 days of ages. At this ages the chicken of the feed conversion ratio line were put in individual cages for measuring feed conversion ratio from 3 to 6 weeks of age. The number of chicken of this line was restricted by the number of cages available. Animals from the growth rate line stayed on the floor until slaughter (6 weeks). To produce offspring for the next generation breeding animals for both lines were kept individually in cages and females were artificially inseminated. All the chickens that described above were reared under continuous light and fed *ad libitum*. All animals received a pelleted broiler diet with 13.4 MJ metabolizable energy and 21.5 % crude protein. Vaccination was also done according to standard procedures.

Measurements

For the BW line, at 41 days of age males and females were separated by a wire mesh fence and were fasted for 12 hours then weighed. The FCR line, at 21 days of age, 144 males and 144 females from each hatch (chosen at random, but approximately equal number per full sib family) were weighed and transfered to individual battery cages with individual feeders. Individual 21 and 42 day live weights were obtained after the birds were fasted about 12 hours. From 21 to 42 days of age weight gain and feed consumption were measured. Feed conversion was calculated by the ratio of feed consumed between 6 and 3 weeks and body weight gain from 3 to 6 weeks old. The parameters analysed in this study were : body weight and feed conversion for the chickens in the FCR line, and only body weight at 6 weeks in the BW line.

Statistical analysis

Means and coefficients of variation of each trait were calculated for each sex and line group. Variation coefficients were used to compare the variability of the trait examined. The fixed effects of hatchyear, sex and their interactions on the performance have been analysed by the GLM procedure of the SAS software package (SAS Institute, 1996). Levene’s test was used in order to test the differences of variances on body weight and feed conversion ratio (SAS, 1997).

To estimate heritability, two methods were used in this experiment. First, estimated variance component using animal model and second, realized heritability using regression of phenotypic means on cummulative selection differential.

The estimate of heritabilities, breeding values, phenotypic and genetic correlation was conducted with the aid of the package ASREML (Gilmour *et al*, 1998). The second method of estimating heritability is realized heritability. These realized heritabilities were calculated over 9 generation of selection in the two selection lines by regression of generation mean of chicken on cumulative selection differential. Selection differential for body weight and feed conversion ratio were calculated by the difference in phenotypic mean value between the selected parents and the chickens of the parental generation before selection.

RESULTS AND DISCUSSION

General Statistical Analysis of the Data

Means and standard deviation of each trait in male and female chickens in both lines are shown in Table 1.

Table 1. Means and standard deviation of analysed data

Traits	BW line		FCR line	
	N	Mean ± sd	N	Mean ± sd
Body weight M (g)	4354	2459.32 ± 271.70	2257	1779.74 ± 195.90
Body weight F (g)	4709	2131.02 ± 215.78	2405	1581.09 ± 157.77
Feed conversion ratio M			2257	1.61 ± 0.07
Feed conversion ratio F			2405	1.70 ± 0.08

Note : M= male; F= female; N= number of observation

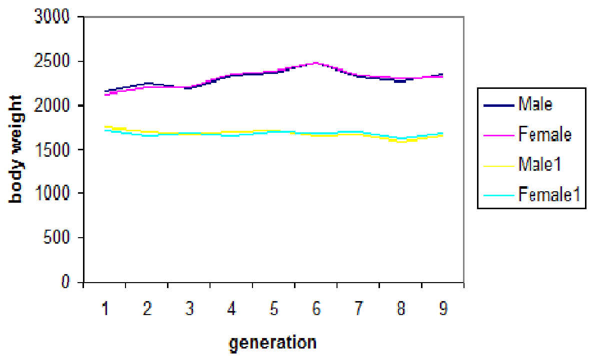

Figure 1. The average body weight of males and females on BW line and FCR line

Figure 1 showed that body weight at 6 weeks of age in the growth rate line tended to increase slightly from generation 1 to 9 for both males and females, whereas a small decrease was found in the FCR line. The feed conversion line showed also the same tendency. This phenomenon was associated with the decline of body weight on this line.

The result of analysis of variance of body weight on both lines and feed conversion ratio of FCR line are given in Table 2.

Table 2. Results of analysis of variance (F-values) of body weight on both lines and feed conversion ratio

Effect	Df	BWL1	BWL3	FCR
Sex	1	0.18	1.16	0.12
Hatchyear	17	145.51**	20.89**	79.22**
Sex x hatchyear	17	2.78**	3.07**	4.35**

** P<0.001

The influence of sex, hatchyear and their interaction was highly significant (P<0.001) in both lines for all traits examined. Male chickens weighed have a larger body weight in this experiment. However, there were large variations on body weight in both lines from first generation to the ninth generation, while feed conversion ratio was more stable in variation

Estimates of genetic parameters

Estimates of heritabilities of, derived from animal model analysis (REML), phenotypic and genetic correlation between the two traits were shown in Table 3.

Table 3. Heritability of (diagonal) and phenotypic (below diagonal) correlation between body weight and feed conversion ratio in both lines

Traits	BW6 (BW line)	BW6 (FCRline)	FCR (FCR line)
BW6(BW line)	0.4153 (0.0302)	0.5907 (0.0348)	0.1839 (0.0627)
BW6(FCR line)		-0.0267 (0.0379)	0.4390 (0.0360)
FCR (FCR line)			

between brackets: the standard error

The estimates heritability of body weight in BW line and FCR line were 0.4153 and 0.5907, respectively. The heritability of feed conversion ratio was 0.4390. Genetic correlation between feed conversion ratio and body weight was positive while the opposite sign was found for phenotypic correlation.

Genetic trends

Genetic trend of the two traits were presented in Figure 2 and 3.. This trend was derived from average breeding values from the REML analysis. The genetic level for body weight in BW line was notably increased by selection (although phenotypic trends showed in different way). The same trends was also found on chickens of FCR line, though only about 18.38% of BW line.

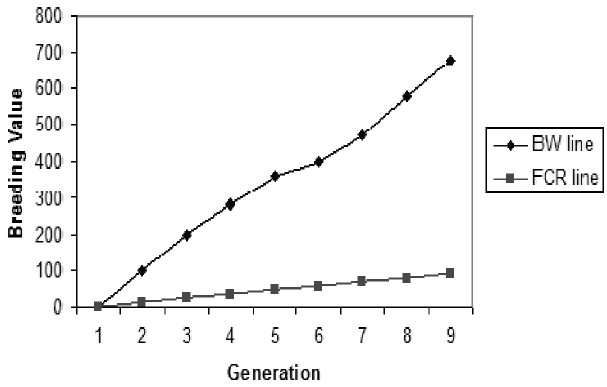

Figure 2. Genetic trend of body weight

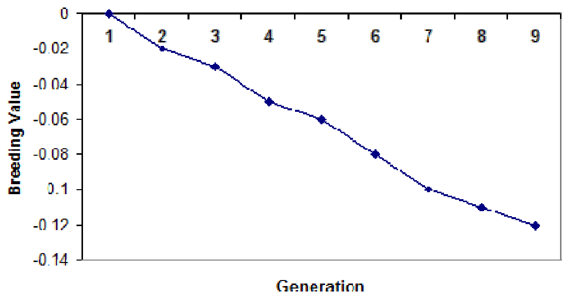

Figure 3. Genetic trends of feed conversion ratio

Selection differentials and Realized heritabilities

Phenotypic means of selected parents and male and female chickens from the same generations on the two lines of the two traits were shown in Table 3. 4. Using regression of generation means on cummulative selection differential, the estimated realized heritabilities were 0.10, -0.14 and -0.03 for body weight BW line, body weight FCR line and feed conversion ratio, respectively.

Phenotypically, positive trends were observed on body weight in BW line both for male and female chickens. However, the increase in body weight for male chickens was higher than for female chickens. Using regression of means body weight on generation, the estimates of increasing body weight were 20.42 gram and 18.56 gram for male and female chickens, respectively. The opposite trends were found in body weight in FCR line. The decrease in body weight was 14.78 gram and 2.98 gram for male and female chickens, respectively. Both trends are in accordance with the expectation from the selection trait. The feed conversion line only considered selection for FCR, without considering body weight. In spite of this there were heavier chickens but if the FCR was unfavorable, they did not become candidates for the next generation. The difference in body weight between these lines was about 36.58% in favour of FCR line. Guil and Washburn (1974) revealed that selection for improved feed convertion ratio would produce a bird that gains slower, consumes less feed but converts feed to body tissue somewhat more efficiently than those birds produced by selection for gain. Generally body weights of male chickens were higher than female chickens. Some authors also reported different body weight responses in males and females. These differences were likely related to different growth rates and variances between sexes (Marks and Washburn, 1983; Marks, 1994). However in this study, body weight increased only slightly, when related to the high standard deviation. The trends on feed conversion ratio for male and female chickens were in different direction. The male chickens have a positive trend of about 0.2% whereas a negative trend was found for female chickens of about 0.11%. BY devinition, the lower feed conversion ratio was more favourable, it meant that male chickens were more efficiently to convert food to body tissue than female chickens. This was caused by phenomenas such as greater competition between males, different nutritional needs in the males and females or greater impact of harmones for fatness in females could be involved (LE Bihan-Duval, *et al*., 1998).

In comparison to other experiments (Guil and Washburn, 1974;Chamber *et al*., 1981) the feedconversion ratio in this experiment was favourable (1.61-1.7 for this experiment vs 1.90-2.65 for their experiments). The differences might be caused by rate of growth and measurement interval of the trait (3-6 weeks for this experiment vs 4-8 weeks for their experiment). Washburn *et al.* (1975) revealed that the differences in efficency were due to efficiency of utilization after intestinal absorption and were associated with changes in carcass lipid and carcass moisture contents. Furthermore, carcass lipid content decreased while carcass moisture content increased as the efficiency of food utilization was improved.

The heritability of body weight of this study agreed well with most published (Leclercq *et al*, 1980; Chambers *et al*, 1984; Marks, 1985). However, the magnitude of heritability estimates for FCR line was higher than that for BW line. The differences in magnitude of both lines might be caused by the difference of housing system, individually for chickens of FCR line and as a group for chickens of BW line. As a consequence, chickens in BW line had more competion, social interaction and more space than those chickens in FCR line. To a small extent these differences might also be induced by the different number of birds used in each line. The number of chickens of BW line were much more than those of FCR line (Table 3.1). Becker *et al*. (1984) estimated heritabilities of some traits using sire model in broiler with small number of chickens (311 males and 341 females) and found the heritability estimates smaller than zero and larger than one. The other reason might be the base population of both lines have been previously selected for growth rate for many generation and this would tend to reduce the overall variability of the population. In the trait body weight of FCR line more additive genetic variance appeared to be present than of BW line (Table 4). The heritability estimate of FCR agreed well with most published (Pym, 1990; Wang *et al*., 1991; Chambers *et al*., 1994). Heritability estimation of efficiency of food conversion, either as gain : food ratio or its reciprocal (FCR) vary from approximately 0.1 to 0.6 and average about 0.4 (Pym, 1990).

Table 4. Phenotypic means and cummulative selection differential of selected and unselected chickens for body weight and feed conversion ratio after correcting data

Selected parents		Generation mean		
Male parents	Female parents	Male	Female	csd
		Trait: body weight BW line		
2446.04	2347.41	2153.53	2129.09	0
2523.07	2421.89	2254.88	2212.17	255.42
2455.83	2397.09	2192.59	2208.78	494.37
2611.91	2531.63	2343.08	2355.94	720.15
2578.48	2552.28	2365.72	2380.72	942.41
2719.35	2641.29	2473.19	2483.16	1134.57
2611.54	2507.68	2321.52	2328.85	1336.71
2476.41	2501.42	2277.15	2298.02	1571.13
		2346.09	2323.33	1772.46
		Trait: body weight FCR line		
1785.41	1745.45	1750.94	1715.01	0
1744.81	1646.70	1709.86	1650.12	32.45
1646.70	1722.49	1674.84	1692.79	48.21
1776.83	1723.56	1706.00	1655.46	114.06
1740.70	1738.99	1712.22	1708.73	165.46
1781.28	1743.75	1661.10	1679.69	215.12
1737.11	1754.73	1674.51	1707.14	285.15
1776.79	1694.85	1581.45	1624.59	360.09
1665.99		1659.76	1694.45	437.48
		Trait: body weight FCR line		
1.597	1.632	1.659	1.674	0
1.598	1.627	1.644	1.645	-0.052
1.606	1.621	1.647	1.642	-0.084
1.569	1.606	1.633	1.635	-0.115
1.597	1.610	1.657	1.649	-0.161
1.669	1.704	1.735	1.734	-0.211
1.610	1.627	1.661	1.639	-0.259
1.628	1.639	1.694	1.667	-0.290
		1.623	1.619	-0.338

csd: cummulative selection differentials

The phenotypic correlation, showed negative sign, whilst the genetic correlation was in the opposite sign. The genetic and phenotypic correlation estimates were in agreement with available estimates. Using sire component, Pym and Nicholls (1979) estimated genetic correlation in male and female chickens ranging between -0.29 to -0.16, whereas phenotypic correlations were between -0.01 to -0.06. A possitive genetic corelation means that with increasing body weight feed conversion ratio will also increase. This correlation was presented in Figure 3 and 4 that showed the opposite trends for body weight and feed conversion ratio. The negative correlation indicated that was the opposite direction of body weight and feed conversion ratio phenotypically. This trend was not desirable since for both traits should have different trends to indicate phenotypic gain.

Using REML analysis the genetic level for body weight in both line was notably increased by selection. The regression equation are y = 82.32x – 61.05 and y = 15.13x – 2.58, for BW line and FCR line, respectively. Slopes of the equation indicate that genetic gain of BW line was almost six time higher than those of FCR line. Although phenotypic trends in both line showed slightly progress in body weight, the genetical trend was considerable. Pym and Nicholls (1997) and Le Bihan-Duval *et al*. (1998) obtained the same genetic trend for body weight in broiler chickens. The trends of FCR and body weight shown in Figure 3 and 4, both trends were in agreement with the estimated genetic correlation. The genetic trends of body weight increased from the first to ninth generation, while reverse was found for FCR indicated that there is a progress in genetic level after selection.

The realized heritabilities were considerably low for all traits and disagreed with most available publication (Pym and Nicholls, 1979). Negative signs of the realized heritabilities for the traits in FCR line was hard to explain. The possible reason was that there was no control line for this experiment such that corretion for enviromental variation is not possible. Marks (1994) revealed that without corretion for environmental variation resulted in large fluctuations in heritabilities across generations. Conectedness animals from one generation to another might be another reason for underestimate realized heritability. In this experiment, no chickens were kept for the next generation as a control group. However, using absolute value of heritabilities for all traits it can be concluded that high enviromen effect contributed in the realized heritabilities. Only small additive genetic variation was present in it.

Nevertheles, although food represents about 70% of the total cost of broiler production, breeders have selected for growth rate and body conformation rather than efficiency of food utilization. The reason for this was that it was simpler and cheaper to measure body weight than individual food consumption. Measurements of individual food concumption need much labour and was time consuming. Most of the potential for genetic improvement in efficiency of food conversion will be obtained as a correlated response to selection for growth rate only if there was a high genetic correlation between the traits (Pym and Nicholls, 1979). However according to Koerhuis and Hill (1996), direct selection for FCR was very likely most effetive and practical for a broiler breeding operation, in term of the expected genetic response and the simplicity of the genetic evaluation of selection candidates. Yet, in practical situation farmers wanted to have heavier chickens at slaughterage with feeding efficiencyly. It seems there was a discrepancy for applying feed conversion ratio in breeding operation.

CONCLUSIONS

Chicken selected for body weight have higher growth rate than those selected for feed conversion ratio. Genetically, there was a high progress for all traits on both lines but only slightly progress was found phenotypically for all traits on both lines. The realized heritability resulted in unusually estimates. Using animal model, heritabilities for all traits agreed with published estimates. There is a discrapency of estimates heritability and reaalized heritability.

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