ISSN 1682-8356
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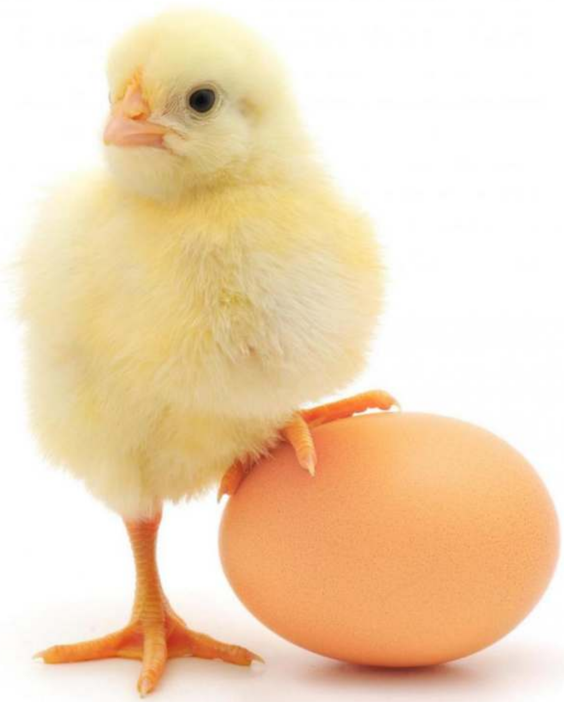

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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International Journal of Poultry Science 8 (10): 952-956, 2009
ISSN 1682-8356

Heritability Estimate and Response to Selection for Body Weight in the Ardennaise Chicken Breed

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Abstract: The aim of this study was to estimate genetic parameters and response to selection for body weight at 11 weeks of age in the Ardennaise chicken breed. Estimations were realized over four generations. From an assumed animal model including fixed effects of hatching year and sex interaction, two models were derived; one included direct genetic and residual random effects; the other included, in addition, random maternal genetic effect. Additive direct heritability was found to be moderate (h^2_a = 0.30), suggesting that selection may be effective in improving body weight and related feed efficiency in our breed. Maternal heritability was low (h^2_m = 0.16) and the genetic direct-maternal correlation was negative (r_{am} = -0.69). Effectiveness of mass selection was confirmed by the phenotypic results obtained in this experiment with body weight increasing from 924.70g (±206.84 g) to 1443.64 g (±145.79 g) in males and from 766.51 g (±176.99 g) to 1128.99 g (±106.26 g) in females. Selection for higher body weight at 11 weeks in as-hatched chickens resulted in more than one and half folds difference in feed efficiency (5.97 in generation 0 vs 3.64 in generation 3).

Key words: Ardennaise chicken breed, body weight, genetic parameters, slow-growing

INTRODUCTION

Genetic progress for body weight or meat production in chickens has been accomplished by continuous selection. Colour-feathered Label meat-type quality poultry, preferred in some parts of the world for meat flavour, meat texture and appearance such as plumage or skin, is produced under systems imposing the exclusive use of slow-growing breeds. The Ardennaise, a traditional Belgian chicken breed, may weigh less than 1 kg at 11 weeks of age (Larivière *et al.*, 2009). Its growth performance may be improved while satisfying *Label*'s requirements by crossbreeding (Larivière and Leroy, 2003) and also through selection. Body weight is influenced by genetic and maternal effects (Liu *et al.*, 1993). In meat-type chickens, genetic parameters of growth have been well investigated. Heritability estimates of body weight at various ages and in different breeds were found to be low to high. Additive heritability for body weight varied from 0.10-0.64 (Siegel, 1962; Danbaro *et al.*, 1995; Koerhuis and McKay, 1996; Le Bihan-Duval *et al.*, 1997; Mignon-Grasteau *et al.*, 1999). Lower values (0.02-0.24) were observed for maternal heritability (Koerhuis and Thompson, 1997; Mignon-Grasteau *et al.*, 1999). Nevertheless, most of these studies have been conducted with fast growing broiler chickens and very little was achieved with slow-growing traditional breeds. The aim of this study was to estimate heritability and response to selection for body weight in the slow-growing Ardennaise chicken breed.

MATERIALS AND METHODS

Subjects, husbandry and feeding: Ardennaise day-old chicks were obtained over 4 consecutive years, corresponding to four generations (G): G_0, G_1, G_2, G_3. Chickens were selected on superior Body Weight (BW) at 11 weeks. The number of breeding sires and dams used per generation are depicted in (Table 1). G_0, composed of 6 males and 29 females, was issued from 2 hatches (269 chicks) obtained from a local fancy breeder. From each of the 6 full-sibs/half sibs groups of G_0, one sire and 3-10 hens were placed in a pen and were used to constitute G_1. In G_1, one of the 6 sires was discarded because all eggs from its breeding pen appeared to be infertile. G_2 was selected in the same way from the remaining 5 full-sibs/half sibs groups of G_1. G_1 and G_2 were composed of 56 and 58 females and of 5 males, respectively. Thus, the pedigree file was composed of 792 individuals. Trapnesting was not carried out during the experiment. For each generation, chicks were hatched, identified with a unique numbered wing tag, vaccinated by injection against Marek's Disease, dispatched and reared in closed pens, each measuring 1.4 m x 1.5 m x 2 m (width x depth x height), with floor litter (wood-shavings), waterer (10 nipple drinkers) and one feeder (metal hopper). Birds were fed an *ad libitum* typical "Label" mash diet (lower energy and protein than commercial broiler diets, genetically modified organism-free and with no coccidiostats) (Table 2) with continuous supply of water. The starter diet (2937.25 kcal, 22% C.P.) was given during the first two weeks of life and the grower diet (3034.42 kcal, 20% C.P.) between 3 and 12 weeks of age. The light schedule followed standard broiler recommendations (Aviagen, 2002) from day-old till end of each growing period with 23 h light and 1 h dark. Fluorescent light intensity measured at floor levels in all pens with a

Table 1: Generation, year, number of sires and breeding hens used

Year	Generation	Sires	Breeding hens
2003	G_0	6	29
2004	G_1	5	56
2005	G_2	5	58
2006	G_3	-	-

Table 2: Composition proportions (%) of the diets fed to the Ardennaise chicken

	Diets	
Ingredients	Starter	Grower
Wheat	27.04	21.46
Wheat + enzymes	10.0	10.0
Soybean meal	31.92	27.13
Corn	25.0	35.0
Chalk	0.50	0.72
Soybean oil	2.23	2.70
DL-Methionine	0.19	0.16
L-Lysine HCL	0.10	0.14
Dicalcium phosphate	1.92	1.63
Vitamin mix	0.01	0.05
Mineral mix	1.00	1.00
Essential oils	0.1	0.0
Laboratory analysis		
Dry matter (g/kg)	25.89	25.26
Ash (g/kg)	56.09	53.64
Fat (g/kg)	43.06-90.0	49.64-70.0
Crude fiber (g/kg)	872.24	872.72
Crude protein (g/kg)	220.0	200.0
ME (kcal/kg)	2937.25	3034.42

digital luxmeter (Mavolux-Digital, Gossen-Metrawatt GmbH, Germany), ambient spot brooding temperature and stocking densities were as described in Larivière *et al.* (2009). At 11 weeks, a total number of 791 chickens, from G_0, G_1, G_2 and G_3, were weighed individually with a hanging scale (Salter Brecknell, 235-6S model, U.K.) and the total amount of food consumed was recorded using the same equipment to calculate cumulative Feed Conversion Ratio (FCR).

Statistical analysis: A preliminary analysis using PROC GLM (SAS, 1989) showed that the interaction between hatching year and sex was significant. Genetic parameters were estimated with DFREML (Derivative Free Restricted Maximum Likelihood) methodology using MTDFREML package programs (Boldman *et al.*, 1995). From an assumed animal model including fixed effects of hatching year and sex interaction, two models were derived; one included direct genetic and residual random effects (model 1); the other included, in addition, random maternal genetic effect (model 2). Written in matrix notation, these models were:

Model 1: $y = Xb + Z_1a + e$,

Model 2: $y = Xb + Z_1a + Z_2m + e$,

where y is the vector of BW at 11 weeks; b is the vector of fixed effects; a and m are vectors of direct animal additive genetic and maternal genetic effects, respectively; X is an incidence matrix for fixed effects; Z_1, Z_2 are incidence matrices for a and m effects, respectively and e is the residual vector.

RESULTS AND DISCUSSION

Direct and correlated responses to selection for body weight at 11 weeks: In our selection experiment for BW at 11 weeks, direct and correlated responses were observed for BW and FCR, respectively. This can be seen in the differences between generations where G_3 selected males and females were 1.5 fold heavier than the initial G_0 (Table 3). Mass selection over four generations has successfully increased average BW from 924.70 g (±206.84 g) to 1443.64 g (±145.79 g) in males and from 766.51 g (±176.99 g) to 1128.99 g (±106.26 g) in females. Feed efficiency was also improved, resulting in more than one and half folds difference in FCR, decreasing from 5.97 to 5.07 to 3.91 to 3.64 in G_0, G_1, G_2 and G_3, respectively. Improving feed efficiency through its correlated response to selection for BW, remains an alternative approach to avoid direct individual measurements of food intake. BW at 11 weeks, from G_0 to G_3, increased linearly by 173 g per generation in males (b = 166.6; R^2 = 98%), by 121 g per generation in females (b = 119.6; R^2 = 98%) and by 155 g per generation in as-hatched chicks (b = 143.4; R^2 = 98%) (Fig. 1). FCR decreased linearly by 0.78 per generation in as-hatched chicks (b = -0.82; R^2 = 95%) (Fig. 2). In comparison to broilers, our selected Ardennaise population for BW at 11 weeks remained at least four times lighter (1285 g < 5521 g) than a popular strain (Ross 308) at 12 weeks and fed a commercial diet in intensive conditions (Havenstein *et al.*, 2003). FCR was also nearly 1.5 times higher in the selected Ardennaise (5.09 > 3.64) than in broilers. Similarly, a review on performance of French traditional breeds showed that Géline de Touraine, Gournay, Noire de Challans and Gasconne breeds as well as a Bresse line (B99), weighing 2000-3600 g between 84 and 186 days of age, had a FCR varying between 4 and 6.6 (Tixier-Boichard *et al.*, 2006). The higher BW in these breeds may be explained by previous selection on this trait. Evidence of undesired effects of increased BW such as leg weakness or sudden death syndrome was not observed at this stage of selection of our experiment.

Genetic parameters estimates for body weight at 11 weeks: Additive direct heritability for BW of both sexes was found to be moderate in every model (h^2_a = 0.29-0.32, Table 4). This result is within the range of values found for growth traits in meat-type chickens aged 8-12 weeks (Le Bihan-Duval *et al.*, 1997; Mignon-Grasteau *et al.*, 1999; Koerhuis and Thompson, 1997) and in unselected local chicken breeds aged 8-12 weeks: Gèline de Touraine breed In France, h^2 = 0.56 (Tixier-

Table 3: Response to selection for body weight (g) (± standard deviation) at 11 weeks in the Ardennaise chicken, per sex and per generation, with number of individuals (N)

	Body weight (g) (± standard deviation)					
Generation	Males	N	Females	N	As-hatched	N
G_0	924.70±206.84	54	766.51±176.99	101	821.44±204.01	155
G_1	1094.00±225.82	145	852.45±163.03	139	971.19±320.12	284
G_2	1148.06±135.04	93	913.05±136.23	83	1037.94±182.90	176
G_3	1443.64±145.79	88	1128.99±106.26	89	1285.42±202.59	177

Table 4: Estimates of genetic parameters (± standard error) for body weight at 11 weeks obtained from MTDFREML program

Model	h^2_a	h^2_m	r_{dm}	σ^2_P
1	0.32 (±0.112)	-	-	0.177
2	0.29 (±0.130)	0.16 (±0.104)	-0.69 (0.316)	0.174

h^2_a = direct heritability; h^2_m = maternal heritability; r_{dm} = direct - maternal correlation; σ^2_P = phenotypic variance

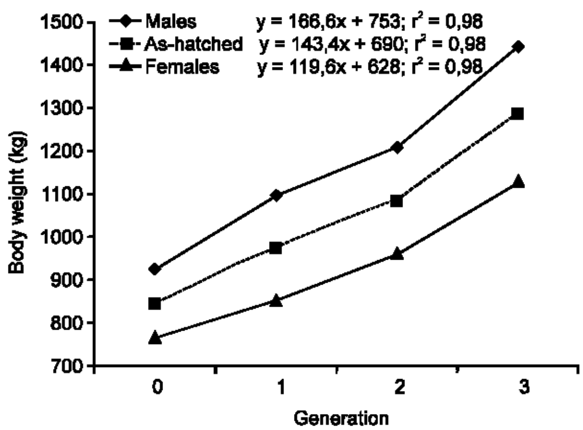

Fig. 1: Linear regression analysis of body weight on generation (G) of male, as-hatched and female Ardennaise chickens at G0 (n = 105 males; n = 54 females), G1 (n = 148 males; n = 143 females), G2 (n = 93 males; n = 83 females) and G3 (n = 88 males; n = 89 females) at 11 weeks of age.

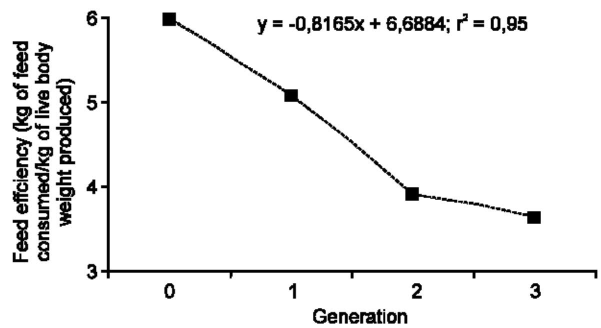

Fig. 2: Linear regression analysis of feed efficiency on generation (G) of as - hatched Ardennaise chickens at G0 (n = 159), G1 (n = 291), G2 (n = 176) and G3 (n = 177) at 11 weeks of age

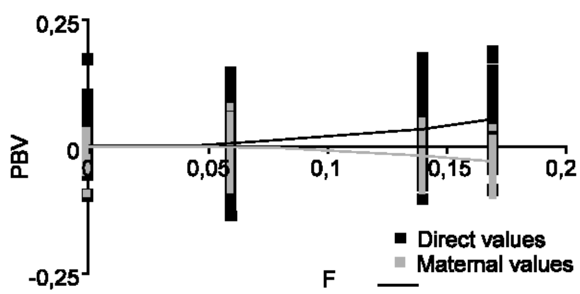

Fig. 3: Relationships between direct genetic and maternal genetic Predicted Breeding Values (PBV) in one hand and the inbreeding coefficient (F) in the other hand

Boichard *et al.*, 2006); Creole breed in Mexico, h^2 = 0.07-0.21 (Prado-Gonzales *et al.*, 2003) and Venda breed in South Africa, h^2 = 0.22-0.41 (Norris and Ngambi, 2006). Siegel (1962), in a summary of 176 published heritability estimates for BW of chickens from 6-12 weeks of age, calculated mean heritability values of 0.41 with an interquartile range of 0.29-0.54. In an experimental study with a French Bresse-Pile strain, heritabilities from sire or dam component varied between 0.42-0.45 for male and female offsprings selected for juvenile BW (8 weeks) and from 0.27-0.61 for those selected for adult BW (36 weeks) (Ricard, 1975). Thus, moderate to high direct heritability with a sufficient genetic variation exists in the Ardennaise breed and other traditional chicken breeds and should allow efficient selection. In addition, other studies suggesting that more efficient selection would be realized on growth curve parameters (Ricard, 1975; Mignon-Grasteau *et al.*, 1999; N'Dri *et al.*, 2006) should be verified in our breed.

The maternal heritability was low (h^2_m = 0.16, Table 4) and the direct-maternal genetic correlation was strongly negative (r_{am} = -0.69, Table 4). In meat-type chickens, Mignon-Grasteau *et al.* (1999) and Koerhuis and Thompson (1997) found similar values of maternal heritability (h^2_m = 0.02-0.24) also lower than the direct ones. Prado-Gonzales *et al.* (2003) and Norris and Ngambi (2006) studying the genetic parameters for BW from hatching to 21 weeks observed that genetic and permanent environmental maternal effects disappeared as of 8 weeks of age. Genetic and environmental maternal effects on chick growth may act before and after hatching. In our study and previous ones, only pre-hatch influence through egg quality would have an effect since chicks were hatched and raised separately from their mothers but this effect seemed more persistent here. A negative direct-maternal correlation was also observed by Koerhuis and Thompson (1997) in juvenile broiler (r_{am} = -0.54) and by Prado-Gonzales *et al.* (2003) and Norris and Ngambi (2006) in local breeds up to 8 weeks (r_{am} = -0.19 to -0.01). The strong genetic antagonism between direct and maternal effect found here means that as far as chicken growth is concerned, genetically heavier hens tend to produce poor quality eggs. Ignoring the environmental covariance between hen and offspring, which is the case here, leads to downward biased estimates of direct-maternal correlation in simulation studies and could also be due to the fixed effects fitted (Bijma, 2006). For broiler chickens, Koerhuis and Thompson (1997) found that models accounting for environmental dam-offspring covariance decreased genetic correlation and that using a more detailed fixed effect structure reduced the absolute values of the estimates.

Selection for BW at 11 weeks being implemented within families, 636 chickens among the 792 animals recorded in the pedigree file were inbred with an average inbreeding coefficient of 11%, varying from 0% in generation G_0 to 6%, 14% and 17% in generation G_1, G_2 and G_3, respectively. If maternal performances are adversely affected by inbreeding, then an individual's phenotype will be influenced not only by its own level of inbreeding but also by its mother's (Lynch and Walsh, 1998). The linear regression coefficients of the predicted breeding value on the individual inbreeding coefficient were estimated as b = 0.33 (± 0.003, p<0.001) and b = -0.19 (± 0.015, p<0.001) for direct and maternal breeding values, respectively. The direct breeding values for BW were improved by selection but at the same time inbreeding increased due to the breeding scheme adopted here. Inbreeding also could impair the maternal performance and affect eggs quality in our case, resulting in decreased maternal breeding values what could contribute to the strong negative direct-maternal correlation. Indeed, during the selection experiment, selection response on BW did not seem diminished by the adverse maternal effects, moreover the predicted response calculated from the estimated genetic parameters was about 175 g per generation in as-hatched chicks and the observed one was about 155 g.

Conclusion: Single trait selection experiments with closed populations provide useful information that cannot be obtained from multi-trait selection experiments or from commercial breeding programs analysis. This experiment resulted in a strong response to selection for BW. Such a selection has resulted in remarkable increases in body size and thereby reduced growth period to produce a marketable chicken with increased feed efficiency. Although Label's requirements are satisfactorily met, there are limitations in selecting Label-type chickens on the basis of BW due to the production system imposition of a minimum fixed slaughter age of 81 days. Moderate heritability suggests that genetic selection for BW may be effective in improving this trait in the Ardennaise chicken breed. Any attempt to formulate a selection program for enhancing the use of traditional breeds would require additional basic research and might be driven by other considerations. As consumers are concerned with obtaining high quality meat, selection of meat-type poultry should also be focused on the improvement of welfare, reproduction and carcass quality like meat yields and body composition.

ACKNOWLEDGEMENTS

Thanks are expressed to the Ministère de l'Agriculture et de la Ruralité, Région Wallonne (Belgium), Thierry Detobel for supplying the Ardennaise hatching eggs, Mr. and Mrs Defays from Ferme de Strée (Modave) for providing facilities, care of the birds and technical assistance.

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