Selection For Excretion Traits In Chicken

H. de Verdal[*], A. Narcy*, E. Le Bihan-Duval*, H. Chapuis[†], D. Bastianelli[‡], N. Même*, and S. Mignon-Grasteau*

Introduction

Poultry production has been criticized for its negative impact on environment, mainly due to the high concentration of poultry farms in several regions of intensive production such as Brittany in France. French meat poultry production was estimated at 2.00 10^6t in 2005, therefore generating a quantity of faeces estimated at 2.97 10^6t for manure and 6.02 10^6t for excreta and liquid manure (CORPEN, 2006). This problem has led to the definition of national and European rules, as the nitrogen directive (91/676/CEE) limiting the nitrogen quantities that can be spread on fields to 170 $kg.ha^{-1}$. Norms are even lower for phosphorus, with a limit of 100 $kg.ha^{-1}$. Some reduction of wastes can be achieved through optimization of feed formulation, but decreasing manure quantity produced by animals through the genetic way would be a complementary novel approach. Until now, selection has mainly been performed on global criteria such as rapid growth or lower FCR. However, the possibility to reduce manure by selecting animals that have a better capacity to digest their feed has hardly been investigated. Indeed, it has long been commonly admitted that ability of animal to digest its feed was not controlled by genetics (Pym 1990), even if several studies quoted that an important individual variability existed on these traits (Maisonnier *et al.* 2001).

Wheat-based diets given to growing chicken were observed to result in low digestibilities compared with corn-based diets (Steenfeldt 2001). Therefore, using a wheat-based diet (55% of the diet), Mignon-Grasteau, *et al.* (2004) showed that digestibility of energy, lipids, proteins, and starch were highly heritable (0.36, 0.47, 0.33, and 0.37, respectively). From this, a divergent selection experiment has been undertaken, using the apparent metabolisable energy corrected to zero nitrogen retention (AMEn) as selection criterion. After 6 generations of divergent selection, AMEn is 42.4% higher in the high digestibility line (D+) compared to the low one (D-, Carré *et al.* 2005). Starch, protein, and lipid digestibility is also improved in D+ compared to D- line (+35%, +8%, and +17% respectively, Carré *et al.* 2007).

The aim of the present study was to estimate the genetic parameters of excretion traits in the two divergent lines D+ and D-, in order to assess the usefulness of selecting on AMEn to reduce manure production.

Material and methods

Birds and housing. The experiment was conducted under the guidelines of the French Ministry of Agriculture for Animal Research. It was carried out on 630 birds of the 9th generation of selection of D+ and D- birds, reared in 3 hatches. At hatching, they were

[*] UR83 Recherches Avicoles, INRA 37380 Nouzilly, France
[†] SYSAAF 37380 Nouzilly, France
[‡] CIRAD, Systèmes d'élevage, 34398 Montpellier cedex 05, France

individually weighed and placed in metal cages of 4 to 5 chicks. After 3 d, chicks were randomly allocated to individual cages distributed in 3 rearing cells, and in each cell, evenly assigned to one of the 3 rows of cages. Environmental conditions were controlled for ventilation, lighting program (24L: 0D from 1 d to 7 d and 23L: 1D after) and temperature (from 33°C at 1 d to 22°C at 23 d). The birds had free access to water and food. They were fed a wheat-based diet similar to the one used in the selection experiment (55% wheat, Mignon-Grasteau *et al.* 2004).

Measures. All birds were individually weighted at 23 d (BW23) of age. Individual total feed intake (FI) was recorded from 17 to 22 d and feed conversion ratio (FCR) was calculated. AMEn, nitrogen and phosphorus excreted (NE and PE) were individually measured between 17 and 22 d, using the method of total collection of excreta (Bourdillon *et al.* 1990). The ratio NE to PE was calculated. Total excreta was collected, dried, and weighed (EW). AMEn and nitrogen concentration of individual freeze-dried excreta were measured for all birds using Near Infrared (NIR) spectrophotometry. Phosphorus concentration was measured by colorimetric analysis. The ratios of EW to FI, NE to FI and PE to FI were calculated. The excreta humidity rate (EH) was calculated as the difference of the fresh to dry excreta reported to the fresh excreta weight.

Statistical analyses. The PROC GLM (SAS Institute, 1999) was used to estimate line and to test which fixed effects (sex, hatch group, cage row, and rearing cell) had to be included in the model for genetic analyses. Genetic parameters were estimated by the Restricted Maximum Likelihood method using the WOMBAT software (Meyer, 2007) and an animal model.

Results and discussion

Elementary statistics on recorded traits are shown in Table 1. Whatever the considered trait, the two divergent lines were significantly different. The selection criterion, AMEn, was 33.5 % higher in D+ than in D- birds in accordance with previous results of Carré *et al.* (2007). D+ birds were 14.4 % heavier than D- birds whereas their feed intake (FI) was 21.0 % lower. Consequently, the FCR was 58.1 % greater in D+ birds than in D-. Furthermore, D- produced 115 % more excreta than D+ birds. Even when correcting for the difference in feed intake, D- still excreted 67.4 % more than D+ birds. This excess was more marked for nitrogen (+53.4 % in D-) than for phosphorus (+21.3 %). This imbalance between nitrogen and phosphorus excretion led to a lower difference in NE: PE (+25.5 % in D-) than for NE: FI. This ratio is important to calculate quantities that can be spread on fields, to take into account the different limits for nitrogen and phosphorus spreading. Considering the fact that about 50 % of nitrogen is lost before spreading, the ratio of 3.46 for D+ birds is close to the optimum. For D-, accounting for a similar loss of 50 % of nitrogen, respecting spreading rules for phosphorus would lead to spread nitrogen in excess by 22 %. Finally, D+ excreta had 7.6 % more humidity than those of D-, which can modify the evolution of excreta in building before spreading, e.g. for gaseous nitrogen losses and also have an important impact on the litter quality.
Genetic parameters are presented in Table 2. The BW, FCR, and AMEn showed moderate to high heritability estimates, consistent with previous results on these lines (0.55 to 0.59 for BW, 0.27 to 0.32 for FCR, and 0.36 for AMEn, Mignon-Grasteau *et al.*, 2004).

Table 1: Elementary statistics on recorded traits for the two divergent lines (Least Square means ± SE)

Trait[1]	n	D+	D-	Line effect[2]
BW23 (g)	592	490 ± 3.62	428 ± 3.62	< 0.01
FI (g)	585	286 ± 3.09	362 ± 3.15	< 0.01
FCR (g:g)	592	1.72 ± 0.08	2.72 ± 0.08	< 0.01
AMEn (kcal/kg DM)	592	3 278 ± 25.6	2 460 ± 25.7	< 0.01
EW (g)	596	62.4 ± 2.68	134.1 ± 2.69	< 0.01
EH (%)	488	70.9 ± 0.52	65.9 ± 0.53	< 0.01
NE: PE (mg: mg)	589	3.46 ± 0.04	4.34 ± 0.04	< 0.01
EW: FI (g:g)	575	0.22 ± 0.01	0.37 ± 0.01	< 0.01
NE: FI (mg:g)	576	11.8 ± 0.16	18.1 ± 0.17	< 0.01
PE: FI (mg:g)	572	3.45 ± 0.04	4.19 ± 0.04	< 0.01

[1] BW23 = BW at 23 d; FI = feed intake between 17 and 22 d; FCR = feed conversion ratio between 17 and 22 d; AMEn = apparent metabolisable energy values corrected to zero nitrogen retention; EW = dry excreta weight; EH = excreta humidity rate; NE: PE = ratio of nitrogen excretion to phosphorus excretion; EW: FI = ratio of dried excreta to feed intake; NE: FI = ratio of nitrogen excretion to feed intake; PE: FI = ratio of phosphorus excretion to feed intake. [2]*P*-value.

Table 2: Estimates of genetic parameters[1] for BW, FCR, AMEn and excretion traits.

Variable[2]	BW23	FCR	AMEn	EW	EH	NE: PE	EW: FI	NE: FI	PE: FI
BW23	0.65	-0.41	0.21	-0.07	0.29	-0.50	-0.20	-0.30	0.07
FCR		0.21	-0.86	0.91	-0.51	0.73	0.88	0.83	0.24
AMEn			0.33	-0.94	0.11	-0.45	-0.99	-0.87	-0.49
EW				0.46	-0.35	0.53	0.95	0.80	0.35
EH					0.26	-0.55	-0.17	-0.22	0.26
NE: PE						0.19	0.45	0.42	-0.37
EW: FI							0.31	0.90	0.51
NE: FI								0.25	0.67
PE: FI									0.24

[1]Heritabilities are on the diagonal, and genetic correlations are above the diagonal. [2] BW23 = BW at 23 d; FCR = feed conversion ratio between 17 and 22 d; AMEn = apparent metabolisable energy values corrected to zero nitrogen retention; EW = dry excreta weight; EH = excreta humidity rate; NE: PE = ratio nitrogen excreta: phosphorus excreta; EW: FI = ratio dry excreta: feed intake; NE: FI = ratio nitrogen excreta: feed intake; PE: FI = ratio phosphorus excreta: feed intake.

To our knowledge, no heritability estimate of excretion criteria has been previously reported. Heritability estimates were high for EW and EW: FI, moderate for EH, NE: PE, NE: FI, and PE: FI, i.e. compatible with selection. EW and EW: FI were positively correlated with NE: FI and PE: FI, but the correlation was stronger with nitrogen than with phosphorus, consistently with the fact that the difference between lines was higher for NE than for PE.

AMEn was highly correlated with EW, EW: FI, and NE: FI, and, to a lesser extent, with PE: FI, showing that selecting on AMEn would reduce manure quantities produced by animals. Such a selection would also modify NE: PE by modifying nitrogen excretion more than phosphorus excretion. Finally, selecting on AMEn would not much affect EH. Even if the evolution of the AMEn was asymmetrical as classically observed in divergent selection experiment, de Verdal *et al.* (2010) showed that the consequences of selection in terms of excretion was more symmetrical when comparing D+, D-, and the control line.

It can be useful to compare potential results of selecting either on FCR as usually practiced to reduce manure in broilers and selection on AMEn. Both reduction on FCR or increase in AMEn would reduce nitrogen and phosphorus excretion. However, from our estimates, selecting on AMEn would lead to a 31% higher response for nitrogen and 156% higher response for phosphorus. Selecting on FCR would reduce NE: PE 29% more than selecting on AMEn, but as 50% of nitrogen can be lost before spreading, such a reduction may not be sought. Finally, selecting on both criteria would increase water content of excreta, which is detrimental to animal welfare by the impact on the litter quality, but this increase would be much higher by selecting on FCR than on AMEn. However, an alternative easier to organize for breeders would be to select directly on EW, which is more heritable than FCR or AMEn and has similar correlations with excretion traits than AMEn. Thus, selecting on EW rather than AMEn would give a 9% higher response to selection on NE: FI and 16% lower response on PE: FI.

Conclusion

The correlations between AMEn and excreta traits, with a wheat-based diet, indicated that selection on this trait would improve manure quantity produced by chickens, without much change in body weight. Selecting on AMEn or on FCR would give results in the same direction, but responses are expected to be greater with AMEn. A combination of selection on FCR and EW would also be an interesting solution.

References

Bourdillon, A., Carré, B., Conan, L., *et al.* (1990). *Br. Poult. Sci.*, 31:557-565.

Carré, B., Muley, N., Gomez, J., *et al.* (2005). *Br. Poult. Sci.*, 46:66-74.

Carré, B., Mignon-Grasteau, S., Péron, A., *et al.*(2007) *World's Poult. Sci. J.*, 63:585-596.

CORPEN (2006). *French Agric. Minister*.

De Verdal, H., Narcy, A., Le Bihan-Duval, E., *et al.* (2010) *13th Eur. Poult.Conf.*

Maisonnier, S., Gomez, J., and Carré, B. (2001). *Br. Poult. Sci.*, 42:102-110.

Meyer, K. (2007). *J. Zhejiang Univ – Sci. B.*, 8: 815-821.

Mignon-Grasteau, S., Muley, N., Bastianelli, D., *et al.* (2004). *Poult. Sci.*, 83:860-867.

Pym, R.A.E. (1990). *Poultry Breeding and Genetics*, p.847-876.

SAS Institute (1999). Version 6, 4th ed. SAS Institute Inc. Cary, NC.

Steenfeldt, S. (2001). *Br. Poult. Sci.*, 42:595-609.