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## Genetic Parameters of Embryonic Viability Traits in a Traditional Chicken Breed

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**Abstract:** The common practice of candling chicken eggs during incubation, allows classification of embryonic mortality at three stages: early, mid-term and late embryonic development. The purpose of this study was to estimate genetic parameters of embryonic mortality at three stages of incubation as well as fertility and hatchability in an ancient chicken breed. Hatchability of fertile eggs had a favourable genetic correlation with early (-0.09) and mid-term (-0.36) embryonic mortality. Hatchability of eggs set was favourably correlated with mid-term embryonic mortality (-0.40) but not with early (0.22) embryonic mortality. Genetic correlations between fertility and hatchability of fertile eggs and hatchability of eggs set were 0.20 and 0.86, respectively. Genetic correlations between late and early embryonic mortality (0.11) and mid-term embryonic mortality (0.34) were favourable, but not between early and mid-term (-0.78) embryonic mortality. Mid-term embryonic mortality and hatchability of fertile eggs were both candidate traits for effective selection against embryonic mortality in our breed. Benefits are brought by the high heritability value of mid-term embryonic mortality and its advantageous correlation with fertility, late embryonic mortality, hatchability of fertile eggs and hatchability of eggs set. On the other hand, it is more convenient to measure hatchability of fertile eggs, which also has a favourable correlation with fertility, early and mid-term embryonic mortality.

**Key words:** Genetic parameters, fertility, embryonic mortality, viability traits, traditional chicken breed

### INTRODUCTION

Avian embryonic mortality has long raised interest at both biological and economical points of view, reducing number of progeny hatched per hen, thus decreasing reproductive efficiency and increasing production costs at breeding and hatching levels. In the domestic fowl, early data suggested that total embryonic mortality in small flocks and those under modern management practices were less than 10% and over 25%, respectively (Romanoff, 1949). More recently, it was observed that early embryonic mortality can affect 33% of fertile eggs in traditional chickens (Hocking *et al.*, 2007) and total embryonic mortality may reach 8% in broilers (Quemeneur *et al.*, 1989 as cited by Beaumont *et al.*, 1997; Scott and MacKenzie, 1993). In turkeys, this percentage may be up to 15% in commercial (Krueger, 1990 as cited by Beaumont *et al.*, 1997) and 7% in traditional flocks (Larivière and Leroy, 2007).

Fertility and viability are multi-factorial traits which could be improved by controlling environmental and genetic factors. Embryonic mortality can be associated with faulty nutrition (Leeson *et al.*, 1979; Wilson, 1997), breeding and husbandry practices (Harry, 1957; Quarles *et al.*, 1970; Baxter and Jones, 1991; Bruce and Drysdale, 1991; Lerner *et al.*, 1993; Deeming and Van Middelkoop, 1999), hatching eggs management before storage (Steinke, 1966; McDaniel *et al.*, 1979; Kirk *et al.*, 1980; Fasenko *et al.*, 1991; Meijerhof *et al.*, 1994), during storage (for a review see Mayes and Takeballi, 1984) or during incubation (Gildersleeve and Boeschen, 1983; Tullet, 1990; Decuyper and Michels, 1992; Christensen, 2001; Elibol and Brake, 2003). In addition to environment

conditions which are usually not optimum in traditional flocks, genetic factors are also responsible for embryonic deaths (Landauer, 1967; Sauveur, 1988; Liptoi and Hidas, 2006). Among the genetic causes of mortality, recessive lethal genes and chromosomal aberrations leading to malformations and malpositions, and polygenic inheritance, have been identified (Landauer, 1967; Sauveur, 1988; Liptoi and Hidas, 2006). Inbreeding will also decrease fertility and/or hatchability (Cahaner *et al.*, 1980; Ibe *et al.*, 1983; Hagger *et al.*, 1986; Nordskog and Cheng, 1988; Flock *et al.*, 1991; Sewalem and Wilhelmson, 1999).

The common practice of candling chicken eggs at 5-10 and 18 days of incubation, allows classification of embryonic mortality at three stages: early, mid-term and late embryonic development. These three mortality stages are likely, at least to some extent, determined by different causes. Very few information on genetic parameters of embryonic viability traits are available in poultry species (Hunton, 1969, in chickens; Singh *et al.*, 1991; Beaumont *et al.*, 1997, in laying hens; Shook *et al.*, 1971; Smith and Savage, 1992, in turkeys; Cheng *et al.*, 1995 as cited by Beaumont *et al.*, 1997, in ducks) and none exist for traditional chicken breeds to our knowledge. The purpose of this study is to estimate genetic parameters of embryonic mortality at three stages of incubation as well as fertility and hatchability in an ancient chicken breed.

### MATERIALS AND METHODS

**Data set:** A total of 2040 hatching eggs from the Ardennaise chicken breed were obtained from natural

mating utilizing 17 sires, each mated to 6-10 hens in one pen, over 3 consecutive years corresponding to 3 generations, G0, G1 and G2, selected on superior body weight at 11 weeks. G0 composed of 6 males and 60 females were issued from 2 hatches (269 chicks) obtained from a local fancy breeder. From each of the 6 full-sibs/half sibs groups of G0, one sire and 6 to 10 hens were used to constitute G1. G2 was selected in the same way from the 6 full-sibs/half sibs groups of G1. Fertility and viability were observed on eggs from hens of G0, G1 and G2. Only one hatch was performed to obtain G1 and G2 composed of 56 and 58 females and of 6 and 5 males, respectively. In G2 one of the 6 sires was discarded because all eggs from its breeding pen appeared to be infertile. Trapnesting was not carried out during the experiment. The pedigree file was composed of 17 sires; the males of G0 were sires of G1 which in turn were sires of G2. Hen age, at the time eggs were first collected, for each hatching year was 46, 59 and 50 weeks, respectively. Hatching eggs, were collected twice a day and uncracked, clean eggs of at least 50 g were marked and identified by sire number, stored at 12-15°C, 70% Relative Humidity (RH), sharp point of egg downward, pre-heated for 12 h at 25°C prior to incubation. A number of 902, 693 and 445 hatching eggs obtained from G0, G1 and G2, respectively were set at random within racks and trays, in a 1100 eggs capacity incubator (model ECO 3, Maino Enrico-Adriano S.N.C., Italy) during 18 days at 37.5°C (60-70% RH) and turned every hour at 90°. Eggs were then placed in individual "pedigree nets" identified with sire number, prior to their transfer in a hatcher (model 11, Maino Enrico-Adriano S.N.C., Italy) during 3 days at 36.5°C (60-70% RH). All eggs were candled individually at 10 days and 18 days, using a hand torch. Clear eggs were removed, opened, inspected macroscopically for evidence of embryo development. In the absence of an embryo, egg was classified infertile and for the fertile ones, embryonic mortality was described as Early (EEM) if observed at day 10, as Mid-Term (MEM) if observed at day 18 and as Late (LEM) if observed after day 21 if unhatched. The binomially distributed analyzed traits were coded as follow: for Fertility (FERT), fertile eggs as '1' and infertile as '0', for mortalities, dead embryos as '1' and living embryos or chicks as '0' and for Hatching Rate of Fertile Eggs (HATF) or Eggs Set (HATS), hatched (emerged chick dead or alive) as '1' and dead embryos or infertile eggs as '0'.

**Statistical analysis:** For each binary trait, we assumed an underlying continuous normally distributed random variable with one fixed threshold delimiting 2 categories. For trait *l*, the heritability estimates and its standard error on the underlying scale were obtained, according to Dempster and Lerner (1950) by multiplying heritability

and its standard error on the observed binomial scale by:

$$[p_i (1 - p_i)] / z_i^2$$

Where  $z_i$  is the height of the ordinate of the normal distribution at the threshold determining the 2 categories of '0' and '1' and  $p_i$  the frequency of '1' for the trait *l*.

The genetic correlations on the normal distribution are identical to that observed on the binary scale (Vinson *et al.*, 1976; Gianola, 1982). The observed environmental correlation estimates between trait 1 and 2 and their standard errors, were transformed to the normal scale by multiplying by:

$$\{[p_1 (1 - p_1)] / z_1^2\}^{1/2} \{[p_2 (1 - p_2)] / z_2^2\}^{1/2}$$

according to Vinson *et al.* (1976).

Genetic parameters were estimated with multiple traits Restricted Maximum Likelihood (REML) method using VCE package (Groeneveld and Kovac, 1990). Model of analysis took into account random effect of the sire and the fixed effect of the hatching year. To estimate variance component for FERT, EEM, MEM, LEM, HATF and HATS, the following model was used:

$$Y_{ij} = \mu + hay_i + sj + e_{ij}$$

Where:

$Y_{ij}$  = Fertility, embryonic mortalities, or hatching rates

$\mu$  = Mean

hay<sub>*i*</sub> = Fixed effect of hatching year (*i* = 1, 2, 3)

sj = Random effect of sire *j*

e<sub>*ij*</sub> = Random residual

## RESULTS

Over the three generations, average percentage for FERT, EEM, MEM and LEM was 58, 14, 7.3 and 30.8%, respectively (Fig. 1). HATF and HATS were 55.2% and 32%, respectively. Heritability estimates on the observed scale from the sire component were low and equal to 0.10, 0.03, 0.10, 0.04, 0.04 and 0.05 for FERT, EEM, MEM, LEM, HATF and HATS, respectively. The genetic parameters estimated on the liability scale for the fitness traits, fertility and viability are given in Table 1. The transformation on the underlying scale increased heritability and environmental correlations estimates from two to three-fold. The heritability estimates transformed to the underlying scale amounted to 0.16, 0.07, 0.30, 0.07, 0.06 and 0.08 for FERT, EEM, MEM, LEM, HATF and HATS, respectively. Their corresponding standard errors were in the range of 0.02 and 0.07. Genetic correlation between FERT and EEM was positive, but was negative with MEM and LEM. Those between the different embryonic mortality stages were positive, except the most significant correlation between EEM and MEM. Transformed estimates of environmental

Table 1: Estimates of genetic parameters for Fertility (FERT), Early (EEM), Mid-term (MEM) and Late Embryonic (LEM) mortalities and Hatching Rate from Fertile Eggs (HATF) or Eggs Set (HATS) (with standard errors) obtained from sire component in the Ardennaise chicken breed. Transformed estimates of heritability on the underlying liability scale (on the diagonal and in bold), genetic correlations (above the diagonal) and transformed estimates of environmental correlations (below the diagonal)

	FERT	EEM	MEM	LEM	HATF	HATS
FERT	<b>0.16 (0.03)</b>	0.45 (0.18)	-0.17(0.18)	-0.29 (0.13)	0.20 (0.21)	0.86 (0.06)
EEM	-0.06 (0.02)	<b>0.07 (0.02)</b>	-0.78 (0.12)	0.34 (0.16)	-0.09 (0.25)	0.22 (0.24)
MEM	0.09 (0.05)	0.26 (0.03)	<b>0.30 (0.07)</b>	0.11 (0.19)	-0.36 (0.19)	-0.40 (0.18)
LEM	0.07 (0.02)	-0.02 (0.02)	-0.07 (0.05)	<b>0.07 (0.02)</b>	-1.00 (0.00)	-1.00 (0.00)
HATF	-0.02 (0.03)	-0.91 (0.04)	-0.93 (0.05)	-1.00 (0.00)	<b>0.06 (0.02)</b>	1.00 (0.00)
HATS	0.93 (0.02)	-0.89 (0.04)	-0.907 (0.05)	-1.00 (0.00)	1.00 (0.00)	<b>0.08 (0.02)</b>

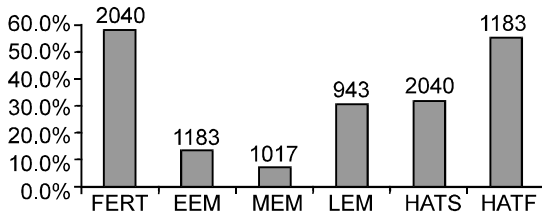


Fig. 1: Total Fertility Rate (FERT) and Hatchability Rate of Egg Set (HATS) and Egg Fertilized (HATF) and total prevalence of Early (EEM), Mid-Term (MEM) and Late (LEM) mortality. Denominators of the ratios (in number of eggs) are above the columns

correlations among FERT and the different embryonic mortalities were irregular and low, with values ranging from -0.06 to 0.09. Those between the different mortalities were negative and close to zero, ranging from -0.02 and -0.07, except between EEM and MEM which was positive (0.26).

Genetic correlations between FERT and HATF and HATS were 0.20 and 0.86 and transformed environmental correlations between the same traits were equal to -0.02 and 0.93, respectively. Genetic correlations between HATS and EEM and MEM were 0.22 and -0.40, respectively and between HATF and EEM and MEM were -0.09 and -0.36.

The transformed environmental correlations between hatchabilities and EEM and MEM were in the range of -0.91 and 0.93. LEM being observed during the hatching period, there was an absolute dependency upon HATF and HATS and genetic and untransformed environmental correlations equated -1.0. Most standard errors of the genetic correlations were relatively high.

## DISCUSSION

The linear procedure used (REML) for the estimation of variance components on the distributional viewpoint is theoretically not suitable for categorical traits (Gianola and Foulley, 1983) and heritabilities and environmental correlations are underestimated. This bias is overcome by transforming estimates on the observed scale to the underlying liability scale (Dempster and Lerner, 1950). Transformed heritabilities are generally slightly overestimated for paternal half-sibs designs. This overestimation increases as heritability rises and as the

prevalence of the character deviates from 50% (Gianola, 1982). As expected, MEM with the lowest prevalence of 7.3% was the most affected by the transformation. An alternative to the present analyze could be a Bayesian method such as Gibbs sampling.

Genetic parameters of poultry reproductive traits generally reveal low heritability, except for sexual maturity (Szwaczkowski, 2003). In literature, heritability of the different stages of embryonic mortality, when analyzed from sire component, varied from 0.01-0.12 (Wilson, 1948; Shook *et al.*, 1971; Brah *et al.*, 1991; Beaumont *et al.*, 1997). The heritability values on the observed scale obtained in our study with the Ardennaise chicken breed was within the range of estimates from these previous studies. Thus, generally, reduction of embryonic mortality would be achieved by improving environment rather than genetics.

Embryonic mortality may be distinguished owing to various stages of embryonic development and these may be considered as distinct traits as reflected by the different heritability values obtained by Beaumont *et al.* (1997) for EEM, MEM and LEM, 0.09, 0.07 and 0.05 respectively. In our study, the transformed heritability value for MEM was moderate (0.30) and low for both EEM and LEM (0.07).

Our estimates of genetic correlations between the three stages of embryonic mortality were irregular, positive between EEM and LEM (0.34) and between MEM and LEM (0.11), but negative between EEM and MEM (-0.78), agreeing with values obtained previously by Beaumont *et al.* (1997). Thus, selection efforts for decreased EEM would result in an increase of MEM in our traditional chicken breed. Environmental correlation between EEM and MEM was positive and significant.

Studies on fertility in chicken or egg laying strains, showed low heritability ranging from 0.01-0.15 (Kinney, 1969 as cited by Liljedahl *et al.*, 1979; Beaumont *et al.*, 1997; Sewalem *et al.*, 1998; Szwaczkowski *et al.*, 2000). Our FERT heritability estimate was comparable (0.16). FERT is considered here as a combined trait of both parents. Heritability for HATF and HATS in literature were 0.02-0.18 (Beaumont *et al.*, 1997; Sewalem *et al.*, 1998; Szwaczkowski *et al.*, 2000) and 0.04-0.19 (Sewalem *et al.*, 1998), respectively and comparable to our results for HATF (0.06) and HATS (0.08). HATF is the ability of a

fertile egg to hatch as a chick and makes more sense on the biological viewpoint than HATS. Moreover, as in Beaumont *et al.* (1997), heritability estimate of HATF is lower than at any embryonic mortality stages.

Our genetic correlations between FERT and the different stages of embryonic mortality are negative thus favourable except for EEM. Selecting the Ardennaise for increased FERT should result in decreased MEM and LEM but increased EEM. Reciprocally, using selection for decreased MEM or LEM should lead to an indirect increase in FERT. Similar results were observed by Beaumont *et al.* (1997) except that MEM, instead of EEM, was unfavourably related to fertility.

HATF and HATS were weakly and negatively genetically correlated with the mortalities (-0.09 to -0.40) except HATS with EEM (0.22). Our environmental correlations between hatchabilities and embryonic mortalities were highly negative (-0.89 to -0.93). Genetic and environmental correlations in the literature varied greatly from -0.95 to 0.95 (Singh *et al.*, 1991; Sewalem and Wilhelmson, 1999).

Genetic correlation between FERT and hatchability was positive, higher with HATS (0.86) than with HATF (0.20) and within the ranges of previous estimates from the literature, varying from 0.30-0.99 (Liljedahl *et al.*, 1979; Chaudhary *et al.*, 1987; Singh *et al.*, 1991; Beaumont *et al.*, 1997). Our environmental correlation between FERT and HATF is not different from zero (-0.02) and high between FERT and HATS (0.93). Similar results were obtained by Chaudhary *et al.* (1987), with HATF (0.03-0.09) and HATS (0.50-0.60).

The distinction of mortality into different stages would allow, in our traditional breed, more effective selection for resistance against MEM and owing to the genetic correlations, with a favourable effect on fertility and hatchability but with detrimental one on EEM. This indicates more opportunity for selection at this midterm stage in the Ardennaise as a mean of improving hatching performance.

Genetic correlations between HATF in the one hand and with FERT, EEM and MEM in the other hand were all favourable, so that HATF, which actually represented the total viability of the fertile eggs could thus be used as convenient selection criteria to improve the reproduction rate in our Ardennaise breed. HATS, which should be considered rather as an economic index, including fertility and viability, showed an unfavourable correlation with EEM.

On the basis of the genetic parameters estimated here and by Beaumont *et al.* (1997), one can conclude that the mortalities at different stages of development should be considered as different traits and owing to higher heritability estimates for these partial mortalities, more efficient selection for resistance to embryonic death should follow. Nevertheless, general rule for selection

cannot be drawn, indeed from sire component genetic correlation estimates of Beaumont *et al.* (1997), selection for MEM resistance would lead to increased EEM but in contrast with our estimates to reduced fertility. Discrepancies between the two studies could be due to breed differences or to the different definition of mortality stages. Actually, the point separating EEM and MEM being on the 7<sup>th</sup> day of incubation in the case of Beaumont *et al.* (1997) and on the 10<sup>th</sup> day in our study. Such a distinction between the mortality traits could ensure more efficient selection for increased resistance to embryonic death.

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