

## **A note on inbreeding effect on productive and reproductive traits in laying hens**

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**Inbreeding rate and effects on production (body weight, age at first egg, egg weight), and reproduction (per cent of eggs fertilized, per cent of eggs hatched as related to eggs set) traits were evaluated in 9194 layers belonging to two strains. The individual inbreeding coefficients were calculated using Wright's formula from available performance records across nine generations. The inbreeding effects (including linear covariable) were estimated by derivative-free restricted maximum likelihood algorithm under an animal model.**

**In general, the inbreeding level appeared relatively low in both populations. The inbreeding depressions for the traits studied (except per cent of eggs fertilized) were found low. The heritability estimates of productive and reproductive traits corresponded with those reported in literature.**

**KEY WORDS: chicken / heritability / inbreeding / laying performance**

Genetic improvement of livestock and poultry is based on two alternative approaches: crossbreeding and selection. Crossbreeding leads to the creation of more heterozygotes and in consequence to greater genetic variation of population. By contrast, selection determines both genetic gain and inbreeding rate. The inbreeding effects include increased homozygosity, a higher risk for the incidence of lethal or deleterious recessive alleles, and decrease in performance and fitness traits [Milgior *et al.* 1995]. On the other hand, mating of relatives has been used over the last centuries to produce breeds, varieties and lines.

In recent years, a number of studies on inbreeding effects in livestock and poultry populations have been performed [Klemetsdal 1998, Thompson *et al.* 2000a, 2000b]. Inbreeding depression in reproductive and productive traits has been reported by Flock *et al.* [1991] and Smith *et al.* [1998]. Therefore, from the current perspective, the inbreeding rate is perceived as negative, especially for small, closed populations. Hence, mating designs with constraints of inbreeding level are developed [Oyama and Mukai 1998, Nomura 1998]. Contrary to livestock, laying hens are characterized by some traits (e.g. short generation interval) which lead to an increase in the inbreeding rate. Jeyaruban *et al.* [1995] reported that the use of best linear unbiased prediction (BLUP) induced larger inbreeding rate compared to selection response, especially for traits of low heritability.

The objective of this study was to evaluate an inbreeding rate and inbreeding effects on some production and reproduction layer traits. The heritabilities of traits studied have also been estimated.

### Material and methods

The report is based on 9194 performance records of two strains (H77 – White Leghorn and N88 – New Hampshire) of laying hens kept on a pedigree farm for nine generations (years). The number of observations per generation (year) was relatively small because only dams were recorded. The number of individuals per year (within strain) was approximately equal. However, to detect the inbreeding rate, pedigree information on sires, including their parents, was added to the data set.

The chickens were naturally mated (one male was mated to ten females) and kept on litter. The environmental conditions did not considerably change over the generations. The following traits were analysed: body weight (BW), age at first egg (AFE), egg weight (EW), per cent of eggs fertilized (PEF) and per cent of eggs hatched as related to eggs set (PEH). A brief statistical description of the data sets is given in Table 1.

The inbreeding coefficients of individuals were calculated by Wright's approach

**Table 1.** Description of data sets

Trait	Strain					
	H77			N88		
	n	mean	SD	n	mean	SD
Bodyweight (g)	5631	1381	144.9	3563	1783.9	204.5
Age at first egg (days)	5630	156.2	11.6	3563	157.6	34.5
Egg weight (g)	5627	59.2	2.8	3563	60.0	11.2
Per cent of eggs fertilized	5422	87.1	17.1	3463	89.4	17.5
Per cent of eggs hatched (no. of eggs set = 100)	5386	75.5	16.5	3441	78.6	15.3

n – number of individuals.

from available pedigree data across nine generations. The inbreeding coefficients were expressed as per cent.

The following unitrait animal linear model was employed:

$$y_{ijk} = \mu + s_i + p_j + bx_{ijk} + a_{ijk} + e_{ijk}$$

where:

$y_{ijk}$  – an observation of  $ijk$ -th individual,

$\mu$  – overall mean;

$r_i$  – fixed effect of  $i$ -th generation ( $i = 1, 2, \dots, 9$ );

$p_j$  – fixed effect of  $j$ -th hatch period ( $j = 1, 2, \dots, 4$ );

$b$  – coefficient of partial linear regression;

$x_{ijk}$  – inbreeding coefficient of  $ijk$ -th individual;

$a_{ijk}$  – random genetic additive effect of  $ijk$ -th individual;

$e_{ijk}$  – random error associated with  $ijk$ -th observation,

Computations were performed using the DFREML package programmes of Meyer [2001].

## **Results and discussion**

### **Inbreeding rate**

The number of inbred individuals and mean inbreeding coefficients over generations are presented in Figures 1 and 2. Null inbreeding levels in the first two generations were influenced by available pedigree information (birds from generation 0 were treated as base). Generally, in both strains, the inbreeding rates increased, while the number of inbred individuals increased up to the generation 6 and then gradually decreased in the further years. This indicates that over the years the inbreeding level of inbred individuals has increased. Maximum annual mean inbreeding level appeared lower in strain H77 (2.5%) than in N88 (3.5%), both being, as expected, negatively correlated with the number of individuals. In general, both inbreeding levels may be considered as low. It corresponds with results obtained by Węzyk *et al.* [2003] who for the same populations reported the so-called hypothetical inbreeding levels per generation (resulting from the number of sires and dams) being very similar to empiric ones. Majority of reports on inbreeding rate in livestock and poultry populations indicates the increase of inbreeding level over time [Sewalem 1998, Miglior *et al.* 1995].

### **Inbreeding effects**

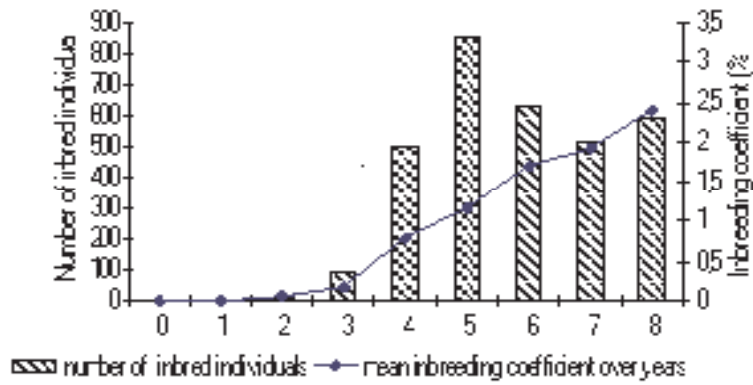


Fig. 1. Inbreeding rate in strain H77.

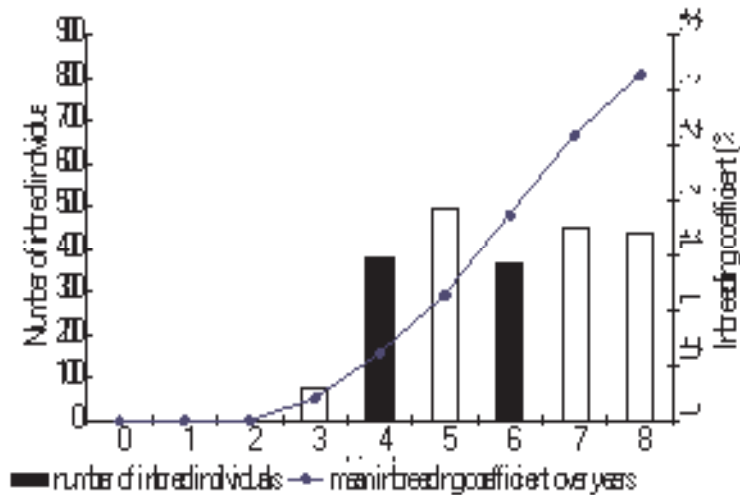


Fig. 2. Inbreeding rate in strain N88.

Table 2 shows estimates of partial linear regression coefficients between inbreeding level (%) and performance traits. Differences between strains were found for the majority of traits studied, pointing to different genetic origin of the strains. Strain H77 has been directly selected for egg production, whereas N88 for more performance traits.

In both populations the deepest inbreeding depression was observed for PEF. Each

**Table 2. Estimates of partial linear regression coefficients inbreeding level-trait**

Trait	Strain	
	H77	N88
Bodyweight (g)	-3.977	3.072
Age at first egg (days)	0.159	-0.128
Egg weight (g)	0.175	-0.589
Per cent of eggs fertilized	-0.403	-0.969
Per cent of eggs hatched (no. of eggs set = 100)	-0.110	0.656

1% of inbreeding of the layer resulted in almost 1.0% and 0.4% decrease in fertilized eggs in N88 and H77 strain, respectively. Different partial regression coefficients (across strains) have been estimated for other traits, for instance in PEH. Various inbreeding effects on some reproductive traits across chicken lines were estimated by a number of authors [Nordskog and Shen Cheng 1988, Gowe *et al.* 1993, Sewalem *et al.* 1999]. On the other hand Hagger *et al.* [1986] concluded that inbreeding was not important for embryonic viability over the extreme range of egg weight. It seems that contrary to mammals, birds can be more responsive to inbreeding rate. This also corresponds with a greater response to chromosomal aberrations in birds described by Sysa and Jaszczak [1997].

Relatively small or moderate inbreeding effects were observed for traits included in the selection index. For instance, 1% increase of inbreeding in layers led to 4 g inbreeding depression in BW for H77 strain. However, for AFE and EW the inbreeding effects were found positive. Reverse relationships were obtained in strain N88.

The annual means of traits studied are listed in Table 3. The means fluctuated negligibly over generations. It seems that these changes were influenced by the inbreeding rate. Piotrowski (unpublished data) reported positive genetic trends for PEF and PEH in the same two populations. Genetic trends for BW, AFE and EW were moderate.

In general, the inbreeding effects in the populations studied were meaningless, except for considerable inbreeding depression obtained for PEF. However, Jeyaruban *et al.* [1995] pointed out that intensive selection based on BLUP led to a high inbreeding rate (about 15%) whereas the genetic gain reached only 5%. Hence, the inbreeding effect obtained can be affected by selection intensity applied to the strains studied. From a statistical point of view, a relatively low inbreeding level of both populations studied is not suitable for evaluating the inbreeding effects.

#### Estimates of heritabilities

A number of reports on heritability estimates of productive and reproductive traits in laying hens have appeared in literature [e.g. Szwaczkowski 2003], and many of the genetic and environmental variance estimates may be helpful in the analysis of inbreeding effects. It is well known that increased inbreeding leads to decreased genetic variation. As listed in Table 4, relatively high heritability estimates were obtained for BW (0.461 and

Table 3. Annual income formation results of economic reforming experiment

Observation	1993									
	1993					1994				
	mean books weight(kg)	regression R <sup>2</sup> (R <sup>2</sup> %)	total weight (kg)	per used of eggs booked	per limited eggs booked (per 1000)	mean books weight(kg)	regression R <sup>2</sup> (R <sup>2</sup> %)	total weight (kg)	per used of eggs booked	per limited eggs booked (per 1000)
1	0.04	0.3	16.9	31.8	77.1	0.1	0.1	16.7	34.3	77.3
2	0.13	0.4	13.9	40.1	67.4	0.6	0.4	16.8	41.3	73.5
3	0.11	0.3	13.1	37.1	77.8	0.3	0.3	16.8	37.7	80.1
4	0.17	0.8	16.4	37.1	76.1	0.9	0.6	14.8	37.1	83.1
5	0.13	0.1	16.3	31.8	79.3	0.1	0.1	16.5	40.4	74.1
6	0.16	0.3	17.1	37.8	74.8	0.3	0.3	16.3	41.1	80.1
7	0.19	0.5	16.5	30.5	79.3	0.5	0.4	16.1	40.5	80.3
8	0.23	0.9	16.1	36.8	84.1	0.6	0.8	16.3	40.1	76.8
9	0.17	0.1	16.3	30.8	71.4	0.2	0.1	16.3	40.6	77.3

**Table 4.** Heritability estimates and their standard deviations (bracketed) of traits studied

Trait	Strain	
	H77	N88
Bodyweight (g)	0.461 ( $\pm 0.030$ )	0.421 ( $\pm 0.035$ )
Sexual maturity age (days)	0.192 ( $\pm 0.029$ )	0.073 ( $\pm 0.033$ )
Egg weight (g)	0.085 ( $\pm 0.021$ )	0.012 ( $\pm 0.015$ )
Per cent of eggs fertilized	0.143 ( $\pm 0.032$ )	0.122 ( $\pm 0.038$ )
Per cent of eggs hatched (no. of eggs set = 100)	0.139 ( $\pm 0.032$ )	0.237 ( $\pm 0.046$ )

0.421 for H77 and N88, respectively). This corroborates the results obtained by Besbes *et al.* [1992] and Tufvesson *et al.* [1999]. However, Szydłowski and Szwaczkowski [2001] reported lower Bayesian estimates of heritability for BW of two Polish strains of laying hens. The estimates of heritabilities for age at first egg obtained by other authors [Sewalem 1998, Szwaczkowski *et al.* 2001] showed variation ranging from 0.08 to 0.44. Heritabilities of PEF and PEH (Tab. 4) are in general agreement with results by other authors for different populations [Sewalem *et al.* 1998, Szwaczkowski *et al.* 2000]. From a methodological point of view it should be noted that these data have not been transformed. It is known that some layer traits exhibit deviations from normality. This led to overestimation of mean square of residuals and, in consequence, to underestimation of heritability. However, from the breeder's perspective an interpretation of inbreeding effects could be difficult, as transformed are also natural units of traits studied. Piotrowski and Szwaczkowski [2002] indicated similar estimates of variance components obtained from untransformed vs transformed data.

The results presented here lead to the following conclusions.

The inbreeding level seems to be relatively low in these populations, undergoing selection. The inbreeding depressions for the traits studied (except per cent of eggs fertilized) are meaningless. The heritability estimates of productive and reproductive traits correspond to those reported in literature.

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## Wpływ inbrodu na cechy produkcyjne i reprodukcyjne kur nieśnych

### Streszczenie

Dokonano oceny poziomu inbrodu i oszacowano jego wpływ na masę ciała (BW), wiek zniesienia pierwszego jaja (AFE), średnią masę jaja (EW), procent zapłodnienia jaj (PEF) i procent wylęgu z jaj nałożonych (PEH). Obserwacje pochodziły od 9194 kur rodu H77 i N88. Współczynniki inbrodu obliczono stosując wzory Wrighta. Poziom inbrodu uwzględniono w liniowym modelu zwierzęcia jako zmienną kowariancyjną. Stwierdzono dość niski (jednak z tendencją wzrostową) poziom zimbredowania, nie przekraczający 3.5%. Generalnie, efekty inbrodu były niewielkie (z wyjątkiem procentu zapłodnienia jaj). Oszacowane estymatory odziedziczalności cech korespondowały z danymi zawartymi w piśmiennictwie.

