Genetic parameters of the traditional selection traits and some clutch traits in a commercial line of laying hens*

Genetische Parameter von traditionellen Selektionsmerkmalen und einigen Merkmalen der Legeserie in einer kommerziellen Legelinie

M. Bednarczyk¹, K. Kieczewski¹ and T. Szwaczkowski²


Introduction

Achievements in poultry population genetics and better environmental conditions have made the manifestation of the genetic potential in laying hens more appreciable and contributed to a substantial progress in their egg production over the previous decades. It resulted, among others, in constriction of the genetic variability in the traditional selection traits, such as number of eggs or laying rate. HUNTON (1984) reported on the limits of laying performance increases in the chicken and even suggested that layers of that time were approaching to their physiological plateau.

In the further studies on the improvement of egg production in the chicken by genetic methods new selection traits have been searched. The studies are based on the known fact that egg production in laying hens is a process of pronounced cyclic nature and eggs are laid at intervals of around 24 to 27h or greater. That cyclic process is the base for the formation of a clutch. In the case of a hypothetic layer demonstrating one clutch, the number of eggs laid is certainly dependent on intra-clutch mean lag phase of oviposition time (LAG). For that reason the selection aimed at reduction of the interval between successive eggs has shown new prospects of progress (MC CLUNG et al., 1976; NAITO et al., 1989; SHELDON and YOO, 1993). Experimental results revealed that in hens of relatively high laying performance, egg production can be improved due to changes in traits being subjected to direct selection.

Having in mind, however, that laying performance in the majority of hens demonstrates at least few clutches, the egg production by an individual layer can be described according to the model suggested by KOOPS and GROSSMAN (1992). In this model the total number of eggs laid over the production period (t) is a function of delay in oviposition time in the particular clutch, and delay in relation to the pause day between clutches. For those reasons it is possible to specify some other measurable traits describing the cyclic laying process which could be used as selection tools such as: clutch number (CN), average clutch size (CS), mean delay of pause day between clutches (DELAY) average clutch length (CL). While the estimates of heritability for oviposition interval within sequences were reported in some papers, the heritability of other clutch traits have been published to a little degree only. In the available literature a report by LUC et al. (1996) was found, concerning the heritability of the above specified clutch traits in laying hens from two experimental lines, divergently selected for high and low yolk to albumen ratio.

The objective of this study was to estimate the heritabilities as well as genetic and phenotypic correlations of the some traits of clutch in a commercial laying hen line, selected so far primarily for egg number by using the classical selection index.

Materials and Methods

Experiment was carried out on Rhode Island White hens of A22 maternal strain, being selected within the breeding programme of “Astra S” layers. That programme has been implemented in the Institute of Animal Husbandry, Poultry Research Branch. The birds were grown on litter and from 18 weeks of age were kept in individual cages under uniform environmental conditions maintained by an automatic control of air temperature, relative humidity and light programme (with light-dark regime about 14hr/10hr). The birds were fed ad libitum on compound feed in mash form.

In the years 1995/96 and 1996/97 the individual laying performance records comprised 2,789 and 2,210 birds, respectively. Pedigree structure of data /population/ was following:

<table>
<thead>
<tr>
<th>generation</th>
<th>number of sires</th>
<th>number of dams</th>
<th>number of daughters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995/96</td>
<td>70</td>
<td>591</td>
<td>2,789</td>
</tr>
<tr>
<td>1996/97</td>
<td>65</td>
<td>526</td>
<td>2,210</td>
</tr>
</tbody>
</table>

The following traits were taken into consideration: body weight at thirty weeks of age (BW); sexual maturity (SM) being understood as the age (in days) of the first oviposition; egg weight (EW) of eggs laid in four successive days in the 33rd week of age and total (20–64 weeks) eggs number (EN). The laid eggs were recorded daily, from the
first oviposition until the 64th week of age with an electronic data collection system (BENDNARZYK et al., 1997). Bar code and hen number expressed in digits in front of the cage could identify each hen. On oviposition by a hen the data coded on the mark were recorded by the LAG-950 Laser Reader, coded in the memory of BCP-601 terminal and then transferred to the PC database.

For each hen, the examined laying cycle was divided into clutches being understood as a series of successive ovipositions. At least one-day-break of oviposition was taken as the end of a clutch. The clutch number (CN), average clutch size (CS) and maximum clutch size (MCS) were calculated. The traits EN, CN, CS and MCS were independently analysed in two periods, i.e. until the 38th and 64th week of age, and they were marked e.g.: EN38, EN64, CN38, CN64, etc., accordingly.

The heritability as well as genetic and phenotypic correlations were estimated within generation on basis the following linear multitrait model:

\[ y_{ijklm} = \mu + h_i + s_k + d_{ijkl} + e_{ijklm} \]

were: \( \mu \) is a overall mean of i-th trait, \( h_i \) is a hatch period fixed effect, \( s_k \) is a sire random effect, \( d_{ijkl} \) is a dam random effect nested in sire effect and \( e_{ijklm} \) is a random residual effect. Additional analysis also included a generation (year) as fixed effect.

It was assumed that sire and dam effects are uncorrelated. The heritability estimates (h²) were obtained from both sire (\( \sigma^2_s \)) and dam (\( \sigma^2_d \)) variances. Thus:

\[ h^2_s = 4\sigma^2_s/(\sigma^2_s + \sigma^2_d + \sigma^2_e) \]

\[ h^2_d = 4\sigma^2_d/(\sigma^2_s + \sigma^2_d + \sigma^2_e) \]

### Results

The phenotypic values of the studied traits in both hen generations are presented in Table 1. Birds of the 1995/96 generation reached their sexual maturity at 154 days of age on average, their mean body weight was 1894 g and egg weight 59.8 g. Initial laying performance demonstrated the following characteristics: EN38 = 94 eggs; CN38 = 11; CS38 = 16.5 days and MCS38 = 42.4 days. The value of those traits, assessed over the period of 64 weeks of age amounted to: 241 eggs, 31.0; 9.4; and 43.9 days, respectively.

Hens of the 1996/97 generation reached their sexual maturity earlier i.e. after 144 days on average, had greater body weight and the eggs proved lower mean weight in comparison with hens of the former generation. The hens of the years 1996/97 demonstrated larger number of eggs regardless of the studied period (38 or 64 weeks), smaller

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**Table 1. Means [x] and standard deviation [s] for egg production traits in two hen generations**

<table>
<thead>
<tr>
<th>Generation</th>
<th>Traits</th>
<th>38th week of age</th>
<th>64th week of age</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EN</td>
<td>CN</td>
</tr>
<tr>
<td>1995/96</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1996/97</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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**Table 2. Heritability estimators and standard error for egg production traits in two hen generations**

<table>
<thead>
<tr>
<th>Generation</th>
<th>Traits</th>
<th>38th week of age</th>
<th>64th week of age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EN</td>
<td>CN</td>
</tr>
<tr>
<td>1995/96</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1996/97</td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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1 SM = sexual maturity, BW = body weight, EW = egg weight, EN = egg number, CN = clutch number, CS = clutch size, MCS = maximum clutch size.
number of clutches and larger length and maximal clutch length in the initial laying period. On the other hand, over the complete laying period until the 64th week of age, the values of clutch traits and the total weight of eggs were greater in the hen generation of 1996/97 compared with those in the 1995/96 generation.

The heritability estimates of these traits within generation and together for both generations (total) are presented in Table 2. These estimates were varied, and were influenced by estimation approach and generation. The highest estimates were obtained for EW (from 0.30 to 0.54), SM (from 0.30 to 0.62), BW (from 0.31 to 0.58) and CN64 (from 0.16 to 0.34). On the other hand, the lowest values of \( h^2 \) were found for the traits EN 64 (from 0.05 to 0.14); MCS38 (from 0.03 to 0.14) and MCS64 (from 0.03 to 0.19).

In the majority of the studied traits the heritability coefficients estimated from dam variance component demonstrated higher values, particularly for SM, EN38, CN64 and CS64, i.e.: 0.52, 0.28, 0.31, and 0.31, respectively, in comparison with those estimated from sire variability, i.e.: 0.34, 0.11, 0.21, and 0.17, respectively.

Greatest differences between the studied generations were noted for SM (0.30, 0.45 compared with 0.47, 0.62) and EW (0.30, 0.39 compared with 0.47, 0.54). In the case of these traits, higher values were found in the hen generation of the years 1996/97.

Genetic and phenotypic correlation estimates of the particular traits are presented in Tables 3 and 4. Clutch traits concerning the CN, CS, and MCS were highly correlated among them in each of the studied hen generation. The genetic correlations were found slightly higher than the phenotypic ones and showed negative values between CN and CS or MCS traits. They ranged from −0.89 to −0.94 or from −0.75 to −0.88 over the period until the 38th week and from −0.98 to −0.99 or from −0.83 to −0.99 over the period until the 64th week of age. Even higher but positive values were noted between CS and MCS (\( r_G = \) from 0.93 to 0.99; \( r_p = \) from 0.64 to 0.73). Attention is to be drawn to the high correlation coefficients, particularly the genetic ones between EN and CN as well as EN and CS, e.g. until the 64th week of age they varied from −0.74 to −0.88 and from 0.81 to 0.90, respectively.

**Discussion**

Data presented in Table 1 demonstrate better laying performance in hens of 1996/97 generation in comparison with those of the earlier one. The differences are in accordance with the trend of selection carried out in A22 hen strain (BEDNARCZYK et al., 1997). The earlier SM (144 versus 155 days) accompanied by the adequate live weight standard favourably affected the EN38 and, EN64. Phenotypic effects doubtless influenced the differences in the magnitude of genetic parameters estimated for both hen generations. In the literature, similarly as in this study, examples can be found of differentiated estimates concerning heritability of EW and BW in birds. However, despite the high amplitude of estimates it has to be stated that the share of genetic variability in the total one is relatively high (BESBES et al., 1992; SZWACZKOWSKI and WEZYK, 1994). The estimated heritabilities were within the top range of those reported by FAIRFILL and GOWE (1990) in their review, and similar to those obtained by FRANCESCHI et al. (1997); WEI and VAN DER WERF (1993); WEZYK and SZWACZYK (1993). One of the reasons for differentiation of experimental results is the specific of the bird popula-

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**Table 3. Genetic (\( r_G \)) and phenotypic (\( r_p \)) correlation coefficients between traits studied until 38 weeks of age (generations 1995/96 and 1996/97)**

<table>
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</thead>
<tbody>
<tr>
<td>EN CN</td>
<td>-0.43</td>
<td>0.38</td>
<td>-0.06</td>
<td>-0.44</td>
<td>-0.47</td>
<td>-0.46</td>
</tr>
<tr>
<td>EN CS</td>
<td>0.54</td>
<td>0.05</td>
<td>0.32</td>
<td>0.53</td>
<td>0.37</td>
<td>0.46</td>
</tr>
<tr>
<td>EN MCS</td>
<td>0.58</td>
<td>0.52</td>
<td>0.51</td>
<td>0.57</td>
<td>0.44</td>
<td>0.51</td>
</tr>
<tr>
<td>CN CS</td>
<td>-0.94</td>
<td>-0.89</td>
<td>-0.92</td>
<td>-0.78</td>
<td>-0.70</td>
<td>-0.74</td>
</tr>
<tr>
<td>CN MCS</td>
<td>-0.88</td>
<td>-0.75</td>
<td>-0.84</td>
<td>-0.70</td>
<td>-0.68</td>
<td>-0.69</td>
</tr>
<tr>
<td>CS MCS</td>
<td>0.93</td>
<td>0.95</td>
<td>0.93</td>
<td>0.73</td>
<td>0.73</td>
<td>0.73</td>
</tr>
</tbody>
</table>

1 SM - sexual maturity, BW - body weight, EW - egg weight, EN - egg number, CN - clutch number, CS - clutch size, MCS - maximum clutch size.

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**Table 4. Genetic (\( r_G \)) and phenotypic (\( r_p \)) correlation coefficients between traits studied until 64 weeks of age (generations 1995/96 and 1996/97)**

<table>
<thead>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EN CN</td>
<td>-0.88</td>
<td>-0.74</td>
<td>-0.83</td>
<td>-0.45</td>
<td>-0.50</td>
<td>-0.45</td>
</tr>
<tr>
<td>EN CS</td>
<td>0.81</td>
<td>0.90</td>
<td>0.83</td>
<td>0.51</td>
<td>0.56</td>
<td>0.58</td>
</tr>
<tr>
<td>EN MCS</td>
<td>0.80</td>
<td>0.79</td>
<td>0.80</td>
<td>0.55</td>
<td>0.44</td>
<td>0.50</td>
</tr>
<tr>
<td>CN CS</td>
<td>-0.99</td>
<td>-0.98</td>
<td>-0.99</td>
<td>-0.80</td>
<td>-0.82</td>
<td>-0.80</td>
</tr>
<tr>
<td>CN MCS</td>
<td>-0.98</td>
<td>-0.83</td>
<td>-0.93</td>
<td>-0.67</td>
<td>-0.59</td>
<td>-0.63</td>
</tr>
<tr>
<td>CS MCS</td>
<td>0.99</td>
<td>0.98</td>
<td>0.98</td>
<td>0.73</td>
<td>0.64</td>
<td>0.69</td>
</tr>
</tbody>
</table>

1 SM - sexual maturity, BW - body weight, EW - egg weight, EN - egg number, CN - clutch number, CS - clutch size, MCS - maximum clutch size.
tions studied by the authors mentioned above. On the other hand, the analysis of their reports can be a basis for the assumption on the existing relation between the method used and the magnitude of obtained estimates. Some authors e.g. WEI and VAN DER WERF (1993) reported that heritability estimated by the animal model demonstrates higher values in comparison with that estimated by the traditional method using hierarchical sire and dam-sire models based on Henderson’s methods. Although, animal model allows on including all the existing relationships between the individuals, that the hierarchical structure of poultry population may be described satisfactory by sire – dam model (HARTMANN, 1989). MIELLENZ et al. (1994) reported very high heritability estimates for BW and EW, i.e. 0.62 and 0.77 respectively, and the authors were not able to explain why the latter value was increasing in the successive generations of birds.

Heritability estimators of SM found in this study differ essentially between generations, from 0.29 to 0.62. Similar tendency was reported by SZWACZKOWSKI (1995) who noted substantial differences among hen strains on the one hand, while a particular data transformation effect indicating the source of potential bias of that trait on the other. According to the author’s point of view the genetic variability structure of SM is not synonymous and he demonstrated that apart from direct additive effects, some nonadditive and maternal effects. Especially for SM we have found an univocally greater the dam, compared to sire variance. It may indicates an important non-additive variability of the trait.

The results concerning EN38 and EN64 generally point to lower assessments in comparison with the other traits and those findings were confirmed in other studies (FRANCESCH et al., 1997; MIELLENZ et al., 1994; SZWACZKOWSKI, 1995). Egg number was the main trait in the selection index that has been used in the improvement of A22 strain for many years. The conducted selection has undoubtedly been the cause of the bias of the estimators.

There are only few studies on heritability of clutch traits, and the existing papers pertain only to estimation of heritability for oviposition interval within sequences (McCLUNG et al., 1976; YOO et al., 1988; NAITO et al., 1989; LILLFERS and WILHELMISON, 1993). Heritability estimators of other clutch traits were found by LUC et al. (1996) only, and it has to be emphasised they dealt with two experimental lines of laying hens, divergently selected for high and low yolk – albumen ratios. Moreover this study was conducted on a small population (the hen population comprised only 81 to 131 birds from each of two studied lines and generations), thus a profound interpretation is not much desired. However the experimental findings reported by the cited authors seem to confirm the reservation presented above. Heritability estimators ranged from 0.12 to 0.83 for CN and from 0.19 to 0.87 for CS. Attention are to be drawn to high standard errors of estimates from 0.11 to 0.39 pointing to a substantial bias of the experimental results.

In our study the clutch traits heritability estimators showed moderate values, however, they were found to be several times greater, particularly in the case of CN and CS (0.15–0.34), compared to with those concerning the EN64 (0.05–0.14). Such low values of the estimated parameters point to minute possibility of effective improvement of A22 birds on the basis of present selection criterion, i.e. number of eggs. It seems, however, that much better results will be achieved taking into account the number of clutches and/or average size of clutches in the selection the studied hen strain. That is much more probable since a close relationship was proved among the specified traits and the number of eggs as witnessed by high correlations, and particularly of genetic correlations.

Summary

The study was carried out on Rhode Island White hens of the A22 maternal strain selected within the breeding programme of Astra S layers. In the years 1995/196 and 1996/97 the individual laying records were collected from 2,789 and 2,210 hens, respectively, kept in cages. Body weight at 30 weeks of age (BW); sexual maturity (SM), i.e. the age (in days) at the first oviposition; weight of eggs (EW) laid in the four successive days at 33 weeks of age and total number of eggs laid (EW) were recorded. Laying performance was recorded daily from the first oviposition until the 64th week of age, using an electronic data collection system. For each hen, the studied laying cycle was divided into clutches, i.e. series of successively laid eggs. The clutch number (CN), average clutch size (CS) and maximal clutch size (MCS) were determined. The EN, CN, CS, and MCS were analysed separately in two periods, until 38 and 64 weeks of age. The phenotypic values of the studied traits were different in both bird generations. Heritability estimates of these traits varied and were influenced by generation and estimation approach and generation. The highest values were noted for EW (0.35–0.60); SM (0.29–0.62); BW (0.38–0.58) and CN64 (0.20–0.34) whereas the lowest ones in: EN64 (0.06–0.14) and MCS64 (0.03–0.21). In the majority of studied traits, the heritability estimated from dam variance component demonstrated higher values, than these from sire component. High heritability estimates of CN and CS suggest that the clutch traits may be effectively used in the selection index of laying hens since those traits are highly correlated with EN64 (0.77–0.90).

Keywords

Layers, genetics, selection, heritability, clutch

Zusammenfassung

Für die Versuche standen Hühner der Mutterlinie A22 der Rasse der Rhode Island White aus dem Zuchtprogramm der Astra S Legehennen zur Verfügung. In den Jahren 1995/96 und 1996/97 wurden bei 2789 bzw. 2210 Tieren eine individuelle Legeleistungsprüfung in Käfighaltung durchgeführt. Die untersuchten Merkmale umfassten: Körperfürtlch der 30. Lebenswoche (BW), Geschlechtsreife (SM, das ist das Tieralter in Tagen beim ersten Ei), Gewicht der in vier aufeinander folgenden Tagen legen Eier während der 33. Lebenswoche (EW) und Gesamtzahl (EN). Die Legeleistung wurde täglich beginnend vom erst gelegten Ei bis zur 64. Lebenswoche erfaßt. Hierzu wurde ein elektronisches Datenerfassungssystem verwendet. Für jede Halle wurde der gesamte Legezyklus in Legeserien (clutches), das heißt in Serien unmittelbar aufeinander folgender Eier, unterteilt. Die Zahl der Legeserien (CN), die durchschnittliche Dauer der Legeserien (CS) und die maximale Legeseriendauer (MCS) wurden bestimmt. Die EN, CN, CS und MCS Merkmale wurden unabhängig in zwei Perioden, nämlich bis zu 38. und bis zur 64. Lebenswoche analysiert. Die phänotypischen Werte der untersuchten Merkmale differierten in beiden Tiergenerationen. Die Werte der Heritabilitätskoeffizienten waren unterschiedlich und hingen vom Merkmal, von der Generation sowie von der Schätzmethode ab. Die höchsten Schätzwerte wurden für EW (0.35– 0.60), SM (0.29–0.62), BW (0.38–0.58) und CN64 (0.20–0.34)
ermittelt, die niedrigsten für EN64 (0,06–0,14), und MCS64 (0,03–0,21). Für die Mehrheit der untersuchten Merkmale wurden auf der Basis der mütterlichen Varianzkomponenten höhere Heritabilitätskoeffizienten geschätzt. Die hohen Heritabilitätszüchtungsätze für CN und CS lassen erwarten, dass die Aufnahme der Merkmale der Legeserie (clutch) in den Selektionsindex bei Legehennen erfolgversprechend ist, da diese Merkmale hoch mit EN64 (0,774–0,902) korreliert sind.

Stichworte
Legehennen, Genetik, Selektion, Heritabilität, Legefolge

References

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