Survival Analysis of White Leghorn Laying Hens in the Early and Late Production Period

Doreen LAMUNO [1]
Gábor MÉSZÁROS [1(✉)]
Esther D. ELLEN [2]
Johann SÖLKNER [1]

Summary

The aim of the study was to carry out survival analysis to evaluate fixed effects and to estimate genetic parameters on survival of laying hens. The data set contained 16,694 records of three purebred White Leghorn layer lines coded W1, WB and WF. At 17 weeks old after rearing, hens were transported to two laying stables and were randomly assigned to traditional 4–birds battery cages. Censoring status i.e. alive or dead was recorded. The traits studied were overall survival during the entire laying period (17 to 64 weeks of age), survival in the early production period (17 to 40 weeks of age) and survival in late production period (41 to 64 weeks of age). The results showed all fixed effects in the model i.e. stable by corridor interaction effect, mortality of back cage neighbors, level and layer lines were highly significant. Overall survival during the entire laying period was 60.4 % while survival during early laying period was 85.1 % and survival in the late laying period was 70.9%. Different risk ratio patterns were observed between the two laying stables. Hens in the top row had about 20% higher risk of death. Number of death cases in the back neighbor cage had a negative effect on the survival. Highest risk of death for line WB and lowest risk for line WF were found. Heritability for survival traits ranged from 0.04 to 0.15. This indicates genetic improvement is possible. Genetic correlation between overall survival and early laying period and between overall survival and late were high, indicating positive correlated response through selection.

Key words

survival analysis, laying hens, heritability, pecking

[1] Univeristy of Natural Resurces and Life Sciences, Vienna, Division of Livestock Sciences, Gregor-Mendel-Straße 33, A-1180, Vienna, Austria
✉ e-mail: gabor.meszaros@boku.ac.at
[2] Wageningen University, Department of Animal Science, Subdivision of Animal breeding and Genetics, Droevendaalsesteeg 1-6708 PB, Wageningen, The Netherlands

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Introduction

Survival analysis is a statistical method used to examine either the length of time an individual survives or the length of time until an event occurs (Ducrocq et al., 2000). A major characteristic of the survival analysis is that it considers both censored and uncensored observations in a single analysis. The length of censored records is used as a lower bound for genetic evaluation of longevity traits. Cox or Weibull models are used to examine survival data. Both models are based on the concept of proportional hazard which defines the hazard function of each individual as the probability of an animal to die or be culled given that it is still alive just prior to time t (Ducrocq et al., 2010; Mészáros et al., 2013). The risks of dying at time t are displayed as hazard ratio or risk ratio. The smaller the risk ratio, the lower is the risk of death and vice versa.

In commercial laying hens, all the hens that survived up to the end of the laying period are culled together while those that die during the laying period are not replaced. After culling, they are replaced with a new generation. However, involuntary culling may occur due to infectious diseases, pecking, cannibalism and accidents. Generally the mortality rate in poultry is low. For laying hens under controlled conditions, the mortality rate is less than 5.2 % per year of egg production (Preisinger, 1998) but it can be higher under loose-housed systems and among birds with intact beaks that show cannibalism and pecking behavior (Alemu et al., 2016; Weeks et al., 2016; Craig & Muir, 1996).

Survival traits are often not included in laying hen selection program due to generally low heritability and high censoring rate which might lead to low selection accuracy. In laying hens, Ducrocq et al. (2000) found heritabilities to be 0.194. Boettcher et al. (1999) reported heritability estimates of 0.04 using the linear model, 0.07 using the threshold model and 0.09 using the survival model. The heritability estimates for mortality of pureline hens in single cages were near zero (Flock, 1996). Research on survival of White Leghorn laying hens, found heritability for survival time using a traditional linear animal model ranging between 2% and 10% (Ellen et al., 2008). They found that social interactions among group members contribute to the heritable variation in survival time. Studies on other species like cattle and pigs report low heritability estimates for longevity (Potočnik et al., 2011; Jovanovac & Raguž, 2011; Mészáros et al., 2010). Cole (2003) looked at the productive life in a population of German Shepherds and Labrador Retrievers bred for use as guide dogs. The author found small linear scale heritability estimates of early working life from 0 to 180 days and late working life from 181 days until retirement in both dog breeds. In German Shepherds, the linear scale heritability for early working life and late working life were 0.032 and 0.018 respectively while in Labrador Retrievers, the linear scale heritability for early working life and late working life were 0.045 and 0.032 respectively.

In laying hens, there is strong interest in increasing survival during the productive life (i.e. length of time a hen spends laying eggs) from 80 to 100 weeks. When survival is increased, the proportion of hens in the late laying period also increases and more eggs are produced per hen or per cage, leading to increased profits. The first aim of the study was to evaluate fixed effects such as stable, line, cage, levels, mortality of back neighbors, and reason for culling in laying hens. The second aim was to compare survival in the early laying period versus late laying period. The third aim was to estimate genetic parameters i.e. heritability (h^2), genetic correlations (r_g) for the traits overall survival days, survival in early laying period, survival in late laying period.

Material and methods

The data was provided by Institut de Sélection Animale B.V. (ISA), a Hendrix genetics company, The Netherlands through partnership between Wageningen University and University of Natural Resources and Life Sciences, Vienna. A detailed description of the data, genetic stock, housing and management are provided in Ellen et al. (2008). The data set consisted of individual records collected on 16,694 purebred White Leghorn female laying hens belonging to three lines W1, WB and WF. The data was collected during only one production cycle in a single generation.

Data was analyzed using the Survival Kit V.6.1 (Mészáros et al., 2013). Genetic parameters were estimated with Weibull model. The general model used to analyze survival data is the hazard function of an individual at time t expressed as:

$$\lambda(t) = \lambda o(t)\exp[X'(t)\beta + z's], \qquad (1)$$

where $\lambda(t)$ is the risk of death at time t, $\lambda o(t)$ is a baseline hazard at time t, which measures the risk of an event to occur given that an individual survived up to time, t. $X'(t)\beta$ represents the fixed effects and $z's$ the random effects. After evaluation of fixed effects, the final model was used for all analysis of data using an animal model and a sire model keeping the same fixed effects.

Table 1. Distribution of layer lines in each laying house stable and cage level

Variable	Class	Stable 1 Number of Observations	Stable 2 Number of Observations	Total	Mean survival days	Standard deviation
Line	W1	3,888	2,346	6,234	354.0	119.0
	WB	3,789	3,111	6,900	325.9	143.9
	WF	2,006	1,554	3,560	375.1	120.1
Level	Top	3,209	0,000	3,209	329.6	136.2
	Middle	3,231	3,500	6,731	352.1	129.5
	Bottom	3,243	3,511	6,754	349.8	130.6

Heritability from sire model was calculated using the formula given in Yazdi et al. (2002)

$$h^2 = \frac{4\sigma_S^2}{\frac{1}{p} + \sigma_S^2}, \quad (2)$$

where h^2 is the heritability, $\sigma_S{}^2$ is the sire variance, p is the proportion of uncensored records.

Heritability for animal model was computed according to Mészáros et al. (2010)

$$h^2 = \frac{\sigma_G^2}{\frac{1}{p} + \sigma_G^2}, \quad (3)$$

where h^2 is the heritability, $\sigma_G{}^2$ is the the genetic variance and p is the proportion of uncensored records

Results and discussion

A fixed effect model that was fitted with stable*corridor interaction, cage level, back cage mortality and line code showed all the effects in the model are significant.

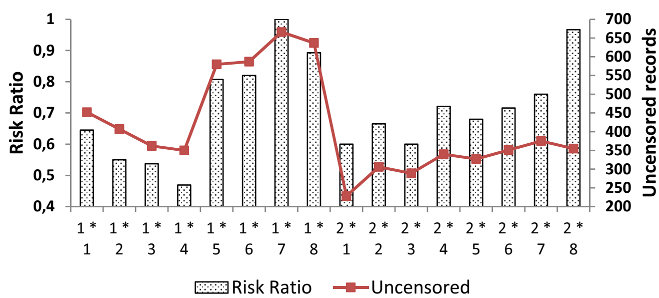

Figure 1. Estimated risk ratios for stable x corridor interaction effect

Hens in laying stable 1 have lower risk ratios and better survival than hens in laying stable 2. This difference could be due to laying house conditions such as light intensity (Ellen et al., 2008). Stable 1 had an effect of daylight from windows and light intensity in stable 1 was lower compared to stable 2. Lighting intensity could influence hen behavior like feeding duration and pecking. A high light intensity might reduce survival rate (Hughes & Duncan, 1972). Differences in risk ratios might be because birds respond to employees with fear. Some birds are threatened and respond with fear while others get used to human contact as reported by Rodenburg et al. (2010) or because of different ages in the corridor.

Hens in the top level (Figure 2) had about 20% higher risk of death compared to middle and bottom cages. The reason for lowest survival in top level could be due to closeness to the light. High light intensity may reduce survival rate (Hughes & Duncan, 1972).

Generally, there is an increasing risk of culling with increase in numbers of death happening in the back cages (Figure 3). Survival is highest when there is no mortality of back neighbors and similar to where the cages had a wall. This result indicates

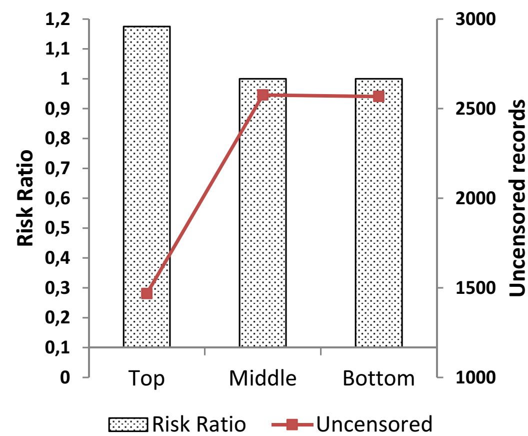

Figure 2. Estimated risk ratios for level

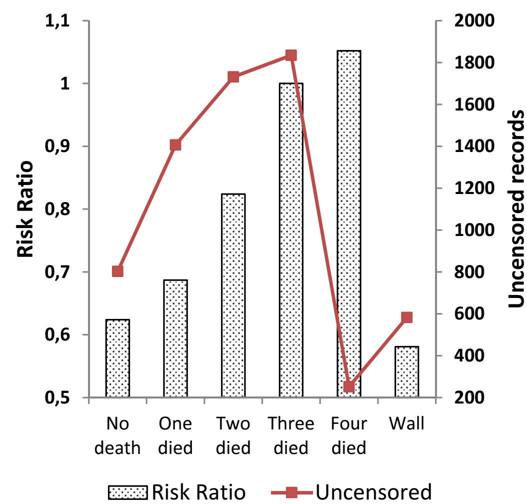

Figure 3. Estimated risk ratios for back cage mortality

that the presence or absence of death cases in back neighbors has significant effect on the survival of cage members. Cage members could possibly copy what they witness. If, for example, they saw their neighbors peck on feathers or on the head, they most likely begin to peck too. Cannibalism is a social behavior that birds respond to (Rodenburg et al., 2010; Rodenburg & Koene, 2003; Sedlačková et al., 2004; Savory, 1995).

There is significant difference between layer lines with regard to survival. Generally, line WB showed the lowest survival followed by W1. Similar findings were reported by Ellen et al. (2008). They found survival rate of 53.9 % in WB and 59.2 % in W1. Line WF appeared with the lowest risk ratio of 0.505, having the highest survival with highest mean survival days of 375.1. Star et al. (2007) also found highest survival days of 351±58 in line WF compared to WB and W1. This same line WF was reported to have the highest survival of up to 74.6 % (Ellen et al., 2008). However in this study, line WF had the smallest sample size of 3,560 birds which could have resulted in the small number of uncensored records.

Table 2. Results for survival, genetic parameters and mean reliability with standard deviation in bracket

Traits	Censored records	Model	Genetic variance	Heritability h^2	Mean reliability
Overall survival	10082 (60.4 %)	Animal	0.328	0.11	0.28 (0.12)
		Sire	0.057	0.09	0.74 (0.08)
Early laying period	14210 (85.1 %)	Animal	0.541	0.07	0.24 (0.11)
		Sire	0.068	0.04	0.58 (0.10)
Late laying period	10073 (70.9 %)	Animal	0.593	0.15	0.29 (0.12)
		Sire	0.071	0.08	0.70 (0.09)

Survival in the early laying period was higher (85.12 %) than survival in the late laying period (70.93 %) and lower (60.4 %) for the entire laying period. This is in agreement with finding of Ellen et al. (2008) where overall survival ranged from 52.9 % to 74.6 % between the three lines. Weeks et al. (2016) found lower survival after 30-35 weeks and they showed that survival in laying hens with intact beaks are generally lower compared to laying hens that are beak trimmed, that have survival of about 95 %. All the laying hens used in our study had intact beaks.

Mortality is higher in the late laying period than in the early laying period. This could be due to pecking. In addition, young birds that are more active and have stronger pecking motivation could develop feather pecking as adults (Newberry et al., 2007). On the other hand, birds also died due to other causes. Among the causes of death recorded were inflammation which could be a result of pecking, bulge cloaca, quail disease, diarrhea, and water belly, some of which do persist throughout life.

Generally, heritability values ranging from 0.04 to 0.15 found are consistent with the heritability estimates of longevity and productive life reported in literature (Mészáros et al., 2010; Piles et al., 2006; Ellen et al., 2008; Ducrocq et al., 2000; Boettcher et al., 1999). Heritability estimates obtained with animal model were higher compared to the sire model. The difference could be due to methods of estimation. The sire model tends to underestimate the heritability as ¾ of additive genetic variance and environmental variance constitute the error variance. The dam variance, Mendelian sampling variance and environmental variance are not taken into account. The heritability in the late laying period is twice the heritability in the early laying period. This implies that the ability to survive in the late laying period is more influenced by genetic background. Meanwhile, heritability in the late laying period is closely related to the heritability for the overall laying period.

High positive genetic correlations were found between overall survival and early laying period (0.83) and overall survival and late laying period (0.93). Therefore, early laying period could be used as a predictor of the total productive life. A lower genetic correlation was found between early laying period and late laying period (0.58). This low correlation indicate that survival in the early laying period and survival in the late laying period are different traits. The low correlation could be due to re-ranking of sires, which means that sires with a good survival during the early laying period, may not have a good survival at the end of the laying period. Therefore, re-ranking of sires could be expected.

Conclusion

Survival traits had low heritability values, but showing prospect for genetic improvement. Early laying period could be used as a predictor of the total laying period especially if the interest is to have an early predictor for total productive life breeding value. Estimation of only one breeding value for overall survival seems appropriate because it reflects the total production period, with high correlations between overall survival versus early laying period and overall survival versus late laying period. The relatively low genetic correlation between early and late laying period means that the two traits are different as there could be re-ranking of animals.

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