A model for predicting hatchability as a function of flock age, reference hatchability, storage time and season

Introduction

In husbandry practice, the hatchery takes over incubation behaviour of hatching eggs in order to provide as many day-old chicks as needed by the farmers. However, several factors influence hatching performance resulting in unexpected number of day-old chicks at the end of incubation. This unpredictable number of day-old chicks constrains hatchery managers to set more eggs than are required in order to meet the demands of poultry farmers.

With advancing breeder flock age, fitness traits deteriorate as well as the quality of the hatching eggs produced. FASENKO et al., (1992) have reported a decline in fertility with the increasing age of the hens. Besides genetic factors, several other factors which also include environmental and management factors have also been shown to influence hatchability. These factors include hen age (LAPÃO et al., 1999; TONA et al., 2004), egg storage condition (BRAKE et al., 1997; LAPÃO et al., 1999; TONA et al., 2003, 2004), eggshell quality (ROQUE and SOARES, 1994), frequency of egg collection (FASENKO et al., 1991), mating ratio (SALISBURY, 1992) and maternal nutrition (WILSON 1997). The influence of weather (i.e. season of production) on hatchability has not been adequately studied in the chicken. This may also influence egg quality before incubation especially during summer when environmental temperatures are high.

However, TULLETT and SMITH (1993) showed that duck eggshell porosity decreased in summer resulting in lower hatchability at this period. BEDNARCZYK and ROSINSKI, (1999) also noted seasonal changes in the hatchability of waterfowl and goose eggs. With this array of factors influencing fertility and hatchability, there is a need to be able to predict the hatchability of the eggs from a breeding flock of hens as they age. This is essential in the sense that management practices and environmental factors may differ between farms. This would enable the optimisation of day-old chick production and thus improve the economic returns of the hatcheries and farmers.

Before incubation, eggs are stored for varying durations for practical reasons (in the all-in, all-out incubation practice). Although this may result in different incubation needs, it has not translated into differential incubation conditions. In addition, as hens grow older, egg characteristics are changing (LAPÃO et al., 1999; TONA et al., 2004), and this may also result in slightly changing incubation needs. Indeed, seasonal effect can interact with the age or storage duration and also with the frequency of egg collection after lay.

In practice, hatchery operators predict a flock's hatchability on empirical basis depending on the age of the breeder flock and egg storage duration. In literature, there is little information on the prediction of hatchability of all flocks from which hatching eggs are collected. Such prediction needs to incorporate all controllable and uncontrollable factors such as flock age, egg storage duration, season of egg production and setting, and previous hatching performances of each flock that forms the source of hatching eggs. A model encompassing all these factors may be used for predicting hatchability as closely as possible to the realized hatchability. Therefore, this study aims to use information about the age of breeder flocks, egg storage duration, season, and reference hatchability of each flock to establish a model for predicting hatchability. This study used data on hatchability, in large-scale conditions to establish the model.

Material and Methods

Experimental design

Hatching eggs produced by 18 different commercial flocks from 9 farms (2 flocks per farm) of Cobb broiler breeders aged from 28 to 60 wk were studied in 205 different incubation settings. The birds were reared under standard commercial husbandry practices. After collection, eggs were stored for 2 to 9 d before setting for incubation. Petersime® incubators 576 and hatchers 192 in Avibel Hatchery Company (Halle-Zoersel, Belgium) were used. For the first 18 d of incubation, a combination of temperature of 37.6°C, relative humidity of 50% and turning once an hour was practised. From d 18 of incubation until hatching, relative humidity and temperature changed as indicated in Table 1.

Four trays of 150 eggs / flock / incubation setting were studied. For each setting, trolleys were chosen at random from each flock. The 16 trays at the front of trolleys were labelled from 1 to 16 from top to bottom. The trays number

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1Department of Animal Production, School of Agriculture, University of Lome, Togo
2Lab of Physiology and Immunology of Domestic Animals, and
3Lab of AgroMachinery and Processing, Katholieke Universiteit Leuven, Heverlee, Belgium

Table 1.
1, 6, 10 and 16 with each containing 150 eggs were observed during the whole incubation period. At the end of each incubation setting (21.5 d), hatched chicks were recorded and their numbers were used to calculate the hatchability in relation to the number of total eggs set. For each incubation setting, data such as flock age, egg storage duration and setting seasons were recorded. For each flock, hatchabilities of eggs stored for less than 7 d and from breeders of 28 (RH28), 38 (RH38) and 48 (RH48) weeks of age were considered as reference hatchabilities.

Statistical analysis

Statistical analyses of the data collected were performed using the SAS/STAT software, version 8 (SAS Institute Inc., Cary, NC, USA). Logistic regression was applied to fit a model to the binomial response variable considering the probability of hatching. The logistic regression model fits the log of the odds by a function of the explanatory variables (Hosmer and Lemeshow, 1989):

\[ \log\left(\frac{\pi}{1-\pi}\right) = \alpha + \sum_{i=1}^{m} \beta_i x_i \]

where \( x \) indicates the explanatory variables (e.g. season, storage time, hen age), \( \pi \) is the probability defined by the proportion of hatched eggs, given a set of m explanatory variables (reference hatchability, age, age x age, storage, storage x storage, age x storage and season), \( \alpha \) is the intercept parameter, \( \beta_i \) is the slope parameter for the \( i \)th explanatory variable and \( x_i \) is the observation for the \( i \)th explanatory variable.

Results

Effects of age of breeders, egg storage duration and seasons on hatchability

Figure 1 shows the hatchabilities of all the flocks in relation to the ages of breeders. Overall, there was a negative quadratic relationship between age of breeders and hatchability (\( P < 0.001; r^2 = 0.78 \)). In general, hatchability was the highest in breeders aged between 27 and 42 weeks and then decreased rapidly until the age of 60 weeks. Hatchability differences between flocks were larger in older breeders.

There was also a negative relationship between hatchability and egg storage duration (\( r^2 = 0.53 \)). Hatchability decreased as storage duration increased (Figure 2). However, the very large scatter between hatchabilities for single storage duration indicates that other factors were interacting with storage duration.

In relation to the season, the hatchabilities were 81.15±1.10, 81.69±0.49, 81.41±0.80 and 79.25±0.58 for fall, winter, spring and summer, respectively. The hatchability of eggs incubated during summer was lower (\( P<0.01 \)) compared to that of eggs incubated in spring, fall or...
winter which were similar. In each season, hatchability decreased with increasing age of breeders and / or increasing storage duration (P < 0.001).

A model for predicting hatchability

A model was obtained using age of breeders, storage duration and season as well as reference hatchabilities. This led to the following model output:

\[ \text{hatchability} = \frac{\exp\left(\alpha + \sum_{i=1}^{q} \beta_i x_i\right)}{1 + \exp\left(\alpha + \sum_{i=1}^{q} \beta_i x_i\right)} \]

where \( \alpha \) is the intercept parameter, \( \beta_i \) is the slope parameter for the \( i \)th explanatory variable and \( x_i \) is the observation for the \( i \)th explanatory variable (e.g. season, storage time, hen age).

Using RH28, Table 2 shows the estimated values of parameters and their significance levels. There was significant linear relationship between the obtained and the predicted hatchabilities. The relationship between the predicted hatchability and the hatchability obtained using RH28 was highly significant (\( r^2 = 0.86; P < 0.001 \); Figure 3). Table 3 shows for reference hatchabilities (RH28, RH38, RH48, RH28+RH38 and RH28+RH38+RH48) the relationships between obtained and predicted hatchabilities. The value of regression coefficient increased with the number of reference hatchabilities included in the prediction formula but was similar between single reference hatchabilities.

Discussion

This study provides relevant model that can be used to predict hatchability. The well known negative effects of increasing age of breeders and / or increasing storage duration were confirmed in this study. Moreover, this study shows clearly that the hatchability of eggs laid or incubated in summer is lower compared to that of eggs incubated in other seasons. In order to formulate this model, reference hatchabilities for each flock were used. For each flock, reference hatchabilities were considered as flock characteristics since management practices are suggested to influence hatchability. The combination of the effects of season, age of breeders and storage duration as well as reference hatchabilities were integrated into the model for hatchability prediction. Since the regression coefficient values of the relationships between obtained and predicted hatchabilities were similar for RH28, RH38 and RH48, eggs produced by hens of 28 weeks of age onward can be considered as an indication of flock characteristics. On the other hand, because regression coefficient increased with number of reference hatchabilities, including all previous hatchability in the model in order to predict the following hatchability may lead to a more proficient model that may be more closer to reality.

This study confirms the quadratic relationship between the age of the breeders and hatchability reported by PEEBLES and BRAKE, (1987) and TONA et al. (2004). The slightly low hatchability of the eggs from breeders aged less than 32 weeks may be due to the insufficient embryonic growth. Indeed, eggs from young breeders are small in their size and as embryonic metabolism such as lipid utilisation and respiration increase with embryonic growth (MCLOUGHLIN and GOUS 1999) there may be insufficient nutrients as well.

Table 2. Estimated values of slopes of explanatory variables for 28 weeks
Schätzwerte der Steigungen der beschreibenden Variablen für das Herdenalter 28 Wochen

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimated values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-2.816</td>
</tr>
<tr>
<td>Reference hatchability</td>
<td>2.54</td>
</tr>
<tr>
<td>Egg setting seasons in comparison with winter</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>0.137</td>
</tr>
<tr>
<td>Spring</td>
<td>0.024</td>
</tr>
<tr>
<td>Summer</td>
<td>-0.029</td>
</tr>
<tr>
<td>Age of breeders</td>
<td>0.157</td>
</tr>
<tr>
<td>Age of breeders x age of breeders</td>
<td>-0.002</td>
</tr>
<tr>
<td>Storage duration</td>
<td>-0.078</td>
</tr>
<tr>
<td>Storage duration x storage duration</td>
<td>-0.004</td>
</tr>
<tr>
<td>Age of breeders x storage duration</td>
<td>0.003</td>
</tr>
</tbody>
</table>

* All estimated values are statistically significant (P < 0.001).

Table 3. Relationships between obtained and predicted hatchabilities according to the reference hatchabilities (P< 0.001)
Beziehungen zwischen dem beobachteten und dem geschätzten Bruterfolg im Verhältnis zu den Referenzbruterfolgen (P<0,001)

<table>
<thead>
<tr>
<th>Reference hatchabilities</th>
<th>Relationship between obtained hatchability (X) and predicted hatchability (Y)*</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH28</td>
<td>Y = 0.8112X + 15.206</td>
<td>0.812</td>
</tr>
<tr>
<td>RH38</td>
<td>Y = 0.8X + 15.73</td>
<td>0.802</td>
</tr>
<tr>
<td>RH48</td>
<td>Y = 0.8X + 14.66</td>
<td>0.804</td>
</tr>
<tr>
<td>RH28+RH38</td>
<td>Y = 0.82X + 14.65</td>
<td>0.826</td>
</tr>
<tr>
<td>RH28+RH38+RH48</td>
<td>Y = 0.86X + 11.23</td>
<td>0.854</td>
</tr>
</tbody>
</table>

* All equations are statistically significant (P < 0.001).
as egg shell pores which may affect embryo development. On the other hand, low hatchability in eggs from older breeders (> 52 weeks of age) may be a consequence of the low fertility and low quality of their eggs. Indeed, increasing age of breeders leads to decreasing egg quality (BAINS, 1994; LAPÃO et al., 1999, and TONA et al., 2004). Furthermore, although the effect of storage duration on hatchability is less obvious in this study, the negative effects of age of breeders x storage duration interaction were confirmed.

A critical factor in egg storage is the storage temperature. Current recommendations vary between 13 to 17°C. The temperature conditions for pre-incubation egg holding have to be below the threshold for development, although there is no agreement in the literature about the real level of this physiological zero which ranges from 19 to 28°C as discussed in a review by DECUYPERE and MICHELS, (1992). At the time of oviposition, an egg should have cooled down to 27°C in about 6 hours. When ambient temperature is high (above physiological zero), slow cooling down of eggs could be a problem as this results in slow cell multiplication and abnormal embryos. Under practical conditions, temperature in the poultry is regulated to around 25°C by heating during cold period. Because environmental temperature during summer is most of the time above physiological zero, low hatchability of eggs laid in summer may be due to the high temperature in the poultry house combined with low frequency of egg collection. Indeed, this is a condition that often occurs if eggs are not collected frequently and are kept warm in the nests by the hens sitting on them and/or by the nature of the nesting material (MEIJERHOF, 1994).

It is concluded that age of breeders, egg storage conditions, season of the year and previous hatchabilities can be used to predict hatchability. Using these parameters in the model formula showed a close-fit between the predicted and the actually determined hatchabilities. The predictability of hatchability is improved by including previous hatchabilities. A model for predicting hatchability may be a relevant tool for hatcheries to estimate more closely the number of the eggs to be set in order to obtain the number in poultry house or incubator room may improve hatchability. Increasing age of breeders and/or storage duration as well as hot season adversely affect hatchability. In order to reduce the effects of summer on hatchability, it is recommended that eggs should be collected more frequently. Also, installation of cooling system in poultry house or incubator room may improve hatchability during hot season.

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Summary
The hatchability of 205 incubation settings of eggs produced on 9 farms of Cobb broiler breeders was analyzed. For each farm, data from two successive flocks were analyzed. The age of the breeders for each flock varied from 28 to 60 weeks. The storage time of the eggs varied from 2 to 9 days under practical conditions (15°C and 70% of relative humidity). The hatchabilities of the eggs from breeders of 28, 38 and/or 48 weeks of age and stored for 3 to 7 days were considered as the reference hatchabilities which characterize each flock. The age of the breeders, egg storage time, the reference hatchabilities and the setting season were fitted into a model that could be applied for the prediction of hatchability.

There was a quadratic relationship between the predicted hatchability and the age of the breeders. However, the wide scatter around the mean indicates that other factors, beside the age of breeders affect hatchability. Similarly, storage duration affected hatchability but showed a very wide scatter of about 35 to 40% around the mean. The setting season had a significant effect on hatchability. However, increasing storage duration resulted in decreased hatchability when age of breeders and season were considered. It was concluded that, hatchability is predictable as a function of age of breeders, egg storage duration, season and flock characteristics. The model can be generalized by including previous hatchabilities at different ages to characterize the flock and its management. This model may find application in the prediction of flock hatchability in hatcheries.

Key words
Broiler breeders, flock characteristics, season of the year, hatching eggs, hatchability prediction,

Zusammenfassung
Ein Modell zur Schätzung des Bruterfolgs als Funktion von Herdenalter, Referenzbruterfolg, Lagerdauer und Jahreszeit


Stichworte
Broilerelternziere, Herdencharakteristika, Jahreszeit, Bruterei, Bruterfolg, Schätzung

Abbreviation keys
RH28 = reference hatchability from breeders of 28 weeks, RH38 = reference hatchability from breeders of 38 weeks, RH48 = reference hatchability from breeders of 48 weeks

References

Correspondence: Dr. O. Onagbesan, Lab. of Physiology and Immunology of Domestic Animals, Kasteelpark Arenberg 30, B-3001 Heverlee, Belgium; e-mail: Okanlawon.Onagbesan@agr.kuleuven.ac.be