An Automatic Monitoring of the Hatching Process Based on the Noise of the Hatching Chicks

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ABSTRACT In this manuscript, a new tool is presented for automatic monitoring of the hatching process of eggs without opening the incubator doors. The amount of energy in the noise produced by the hatchlings was registered by means of a microphone and a personal computer for signal treatment. Evidence is shown that it is possible to detect exactly when the first chicks are hatched, the mean hatching time, and the finish of hatch. The information generated by this tool can be used by the hatchery manager to make the decision to end the incubation at the right moment, resulting in a higher number of first quality chicks without the risk of a reduced hatchability due to too early termination of the incubation process. The presented research also shows evidence that there is already a circadian rhythm in the newborn hatchling even when no external stimulus is present.

(Key words: hatching process of chicks, circadian rhythm, noise energy)

INTRODUCTION

A large variation in the hatching times of eggs with in an incubator is commonly observed (Tona, 2003). Therefore, an important decision with potentially severe economic consequences in the management of a hatchery is when incubation is ended by opening the hatchers. If incubation is ended too early, eggs with viable chicks inside are thrown away, decreasing the hatching rate and resulting in economic losses. When hatchers are opened too late, the chicks will experience a longer period of dehydration. Moreover, long delays in access to feed will negatively affect chick performance (Noy and Sklan, 1999; Decuypere et al., 2001; Gonzales et al., 2003), resulting in decreased slaughter weight at 42 d of age. Therefore, the mean hatching time has to be considered by the hatchery manager. Several factors influence mean hatching time.

Some of these factors are flock-dependent characteristics. The age of the broiler parent flock has an inverse effect on hatching time. Different lines have different hatching times (Henderson, 1950; Morgan and Kohlmeyer, 1957). Richards (1959) presented evidence that female chicks hatch earlier than male chicks, but this has been contradicted by other studies (Tona, unpublished results). Other factors are egg related. The size of the egg is positively correlated with the hatching time. (Hassan and Nordskog, 1971).

Also management factors in the parent flock farm and hatchery company have an effect on hatching time. Lundy (1969) mentioned that an increased incubation temperature within the zone of optimal temperature decreased hatching time. Muambi et al. (1980), Tona et al. (2003a), and Tona et al. (2003b) have explained increasing hatching time with increasing storage time of the eggs before incubation. Finally, because temperature gradients are present in the most modern incubators during embryonic development (Van Brecht et al., 2003) and hatching time is related to incubation temperature (French, 1997), differences in hatching time are influenced by the location of the egg within the incubator.

The complexity of the factors affecting the incubation time makes it very difficult for hatchery managers to correctly estimate hatching time and spread from the characteristics of eggs, preincubation period, and incubation itself.

However, to optimize the hatchability and chick quality, time at which the hatching process is finished should be predicted. A possible way is to monitor early embryonic growth to predict the estimated hatching time. Kemps et al. (2003) found a correlation between the moment at which the resonant frequency of an incubated egg started to decrease (after around 100 h of incubation) and the hatching time. Before being of any practical or scientific benefit, a large-scale experiment should be conducted to confirm these results with different lines and under different conditions (e.g., storage length and age of breeder). Despite the potential of the technique, it faces several disadvantages. A small set of eggs has to be placed into a special apparatus in which the resonant frequency can be monitored during incubation. Moreover, factors...
affecting hatching time during incubation (e.g., slight temperature differences) could not be included in the estimation of hatching time, which was tested only under standardized and linear or constant incubation conditions. The potential of differential conditions in time during the incubation makes the use of this technique even more unreliable.

In commercially available hatchers, a monitoring system for the hatching process exists and is based on the relative humidity and CO₂ production in the hatcher (M. Boerjan, 2005, Pas Reform, Zeddam, The Netherlands, personal communication). But a problem here might be the combination of measuring changes in ambient factors and controlling them at the same moment.

To be relevant and practical, it would be advantageous to have a tool that gives a clear indication of the progress of the hatching process itself, independently of all factors that are controlled in the hatcher. During the hatching process, a newborn chick will produce noise, and hence a possible tool might be based on the measurement of the energy in the noise produced by the hatched chicks. In this manuscript, a technique is presented that makes it possible to monitor the hatching process itself.

**MATERIAL AND METHODS**

**Measurement Tool**

A small microphone² attached to the inside top of a middle scale incubator³ was used to capture noises produced by hatchlings. The recorded microphone signal was fed to the soundcard of a portable computer. A software platform written in the Labview 5.1.4 computational language was used to process the noise data. Continuous noise samples of 500 ms were recorded. The noise was recorded mono with 8-bit resolution and a sample frequency of 44.100 Hz. To remove any noise not attributed to the hatchlings, such as the ventilator or the turning mechanism, a digital interpolated finite impulse response (FIR) band pass filter between 2,000 and 6,000 Hz was applied. During a preliminary experiment, these values were found to be the limits of the acoustic noise produced by the hatchlings.

After filtering, the power spectrum was calculated from each sample of 500 ms using Welch's averaging method. An example of such a power spectrum is given in Figure 1. The total energy content of noise produced by the chicks was estimated from the surface beneath the power spectrum to be between 2,000 and 6,000 Hz and, thus, for each 500 ms of noise sample separately. Consequently, a moving average of the total energy in 1,000 noise samples was used to represent the noise evolution curve. Because each measurement point describes the noise energy level of a 500-ms time span, each moving average data point gives the mean energy in the noise for 500 s. With these data, the evolution of energy in the noise produced by the hatchlings could be visualized.

**Experimental Setup**

In 3 separate experiments, energy of the noise was registered during the hatching process. For each of the 3 experiments, 40 fertile Cobb eggs from an unknown parental flock,⁵ already incubated for 19 d in a commercial hatchery, were placed in specially constructed hatching baskets made from metal wiring to hold individual eggs and chicks to keep the chicks from mixing. The baskets containing eggs were placed in a Pas Reform incubator² at 37.6°C, 55% relative humidity, and continuous lighting until hatch. From 20 d till 23 d of the incubation, the energy level in the noise produced by the chicks was monitored automatically with the method described above.

**Monitoring Hatching Time**

To be able to link the noise level with the number of hatched chicks, pictures were taken every 30 min with a digital photo camera⁶ attached to the inside top of the incubator. The pictures were saved automatically on the hard disk of a personal computer connected to the camera; time of capture was also recorded automatically. By comparison of consecutive pictures (Figure 2), it was possible to construct the cumulative hatching curve. In this way, a cumulative hatching curve with a time resolution of 30 min could be made. This accuracy is sufficient to follow the total hatching process.

To exclude the effect of the camera flash on the excitation of the hatched chicks, continuous lighting was pro-

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²Type Electret Tie, Monacor International, Bremen, Germany.
³C-Type, Pas Reform, Zeddam, The Netherlands.
⁴National Instruments, Zaventem, Belgium.
⁵Avibel, Halle-Zoersel, Belgium.
⁶Canon Powershot A300, ICB Computers, Munsterbilzen, Belgium.
vided in the incubator at a sufficient level to take pictures without flash lighting. To prevent chicks from being excited by external noise stimuli, the incubation room was acoustically isolated and locked during the experiment.

**Monitoring Circadian Rhythms Posthatch**

Hatched chicks were removed from the hatcher 100 h after the start of the experiment. Between hatch and removal from the hatcher, the temperature was kept at 37.6°C and relative humidity was at 55%. During this period, measurement of noise continued as described above. Special effort was made to prevent external stimuli from reaching chicks in the hatcher. Therefore, the incubation room was isolated acoustically, and continuous light was provided in the hatcher. The internal temperature and humidity in the hatcher were controlled by the regulation system of the hatcher. Outside the hatcher the temperature was kept continuously at 22°C.

**RESULTS**

In Figures 3, 4, and 5, the noise energy level and the cumulative hatching curves are presented for the 3 experiments separately. During all 3 experiments, energy in the noise increased from the moment the first chicks hatched until the maximal hatch rate was achieved. After this point, the noise level decreased, and later, a cyclic evolution of the energy in the noise was found. It reached a minimum a few hours before the last chicks hatched.

From the curves describing the evolution of the noise in the hatcher, the time of the first increase in noise (i.e., the starting point), the peak of noise during the first cycle, and the time of the first local minimum (expected to be the end of the hatching period) were calculated and are presented in Table 1 as is duration of the 2 first cycles of noise. From the cumulative hatching curve produced with the camera inspection method, the time of the first hatch, last hatch, mean hatching time, and the total duration of the hatching process (i.e., span time) were calculated and are also presented in Table 1.

The start of the first noise cycle and the start of the hatching process as monitored by visual inspection, end of the first noise cycle, and end of the hatching process; the time of the highest peak in the noise cycle, mean hatching time, duration of the first noise cycle, and total hatching time were compared using a paired Student’s t-test. The P-values of these tests are presented in Table 1. As shown, statistical differences could be found among time of the highest peak, mean hatching time, end of the first noise cycle, end of the hatching process. These results indicate that the start of the hatching process coincided with the first noise. Later on, the noise cycle finished earlier as the hatching subsided.

In the hours following hatch, a cyclic evolution in noise content was observed obeying a circadian rhythm (see

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**TABLE 1. Characteristics of the noise data and visual monitoring of the hatching processes**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Start 1st cycle (h)</th>
<th>Stop 1st cycle (h)</th>
<th>Highest peak of 1st cycle (h)</th>
<th>Duration 1st cycle (h)</th>
<th>2nd cycle (h)</th>
<th>Hatching time data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25.75</td>
<td>47.30</td>
<td>36.70</td>
<td>21.55</td>
<td>23.90</td>
<td>28.88</td>
</tr>
<tr>
<td>2</td>
<td>17.7</td>
<td>39.05</td>
<td>28.4</td>
<td>21.35</td>
<td>21.60</td>
<td>17.91</td>
</tr>
<tr>
<td>3</td>
<td>23.30</td>
<td>45.60</td>
<td>31.8</td>
<td>22.30</td>
<td>20.70</td>
<td>25.43</td>
</tr>
<tr>
<td>Mean</td>
<td>22.25</td>
<td>43.98</td>
<td>32.30*</td>
<td>21.73&lt;sup&gt;d&lt;/sup&gt;</td>
<td>22.06</td>
<td>24.07&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>P-value</td>
<td>0.083</td>
<td>0.029</td>
<td>0.031</td>
<td>0.062</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>-<sup>d</sup>Paired Student’s t-tests were made between the groups indicated by the same superscript letter; the P-values for these tests are presented.

<sup>*</sup>Significant difference (P < 0.05).
Table 1). In Table 2, the relation between the monitored noise cycle and the natural day-night cycle is presented, which was determined by selecting the time of the starting and maximal noises for each of the 3 monitored cycles for each experiment. It was observed that the times of the start of the cycles and maximal noise were advancing with subsequent cycles compared with the 24-h day-night cycle. This resulted from the slightly shorter duration of the noise cycle than the diurnal rhythm.

**DISCUSSION**

The start of the hatching process could be clearly observed from monitoring the noise energy in a hatcher during the hatching process (Figures 3–5 and Table 1). From the moment the first chicks hatched, the noise energy in the incubator increased and this could be matched unequivocally with the visual analysis of the hatching process by camera observation. Defining the point of complete termination of the hatching process was more difficult using the changes in energy in the noise. Combining Figures 3, 4 and 5, the energy in the noise increased until it reached its maximum some hours before the maximal hatching rate is registered. When the hatching rate slows down again, the energy in the noise inside the hatcher decreases as well. The time point of completed hatch by camera observation occurred later than the time point of minimal energy in the noise of the hatching chicks and hence the end point of the hatching process was not immediately visible from the changes of the noise energy in the hatcher. However, characteristic events on the noise curve could be related with the time point of total hatch and hence might be used as an estimator for termination of the hatching process of a batch. Since in the three experiments the start of the noise level recordings were realized at exactly the same chronological time (start of d 20 of the incubation) differences in hatching time between the different experiments again point to the importance of different factors influencing incubation length (e.g. breeder age, line, storage time etc.). Influence of incubator could be ruled out here since the same incubator and incubation conditions were used in the three experiments. Apparently, an earlier hatch is not going together with a smaller duration of the hatching process,
as often claimed by commercial hatcheries, indicating that hatching time and spread of hatch are to some extent independent criteria which are differentially regulated.

In Figures 3, 4, and 5, a rhythmic evolution of the total energy in the noise is shown. In Table 1, the periods of the rhythmic evolution are presented for each experiment. According to Ruckebush et al. (1991), rhythmic evolutions with a time period for one cycle averaging 22.6 h are classified as circadian rhythms. Normally, these circadian rhythms are regulated by melatonin, a neurohormone that is produced by the pineal gland and in connection and concert with the photosensitive retina. This melatonin will synchronize specific pacemakers that have to follow a light-dark cycle (Klein et al., 1981). Willbold et al. (2002) provided evidence that a circadian rhythm is present in the chick embryo, even when the embryos are not exposed to a light cycle (e.g., on an endogenous basis).

Our hatching process occurred under continuous lighting; moreover, special effort was made to prevent any zeitgeber\textsuperscript{7} (e.g., noise) from affecting the chicks. Nevertheless, a circadian rhythm in the energy of the noise level was produced by the just-hatched chicks (see Table 1). This circadian rhythm was not matched with the natural day-night cycle (see Table 2), indicating that no external stimuli could reach the newborn chicks. This result could be an example of the presence of an inborn circadian cycle in the chicks without photostimulation of the melatonin-releasing systems in the newborn chick. In view of this, the release of melatonin could be regarded as the synchronizing factor of the natural day-night cycle and several independent circadian pacemakers in the brain of the chick, as already postulated by Willbold et al. (2002).

In conclusion, it can be stated that by monitoring the energy level of the noise from newly hatched chicks, the start of the hatching process and the mean hatching time can be registered easily without opening the incubator. Hatchery managers could use the described evolution of the energy in the noise as an indicator of the progress of the hatching process, and, hence, it could be a useful tool.

\textsuperscript{7}A zeitgeber is an external stimulus that the chick can use to estimate the time. For example the sunset is an important zeitgeber for several animals.
FIGURE 5. Upper panel: recorded energy in the noise level (points) and moving average (thick line). Horizontal lines at the bottom of the figure indicate night (from 1900 h until 0700 h). Lower panel: cumulative hatched chicks as recorded by the camera. Data are from the third experiment. Incubation time after 19 d is presented in the time axis.

in hatchery management. This technique is ready to be tested in large-scale incubators.

Although, to the best of our knowledge, all circadian stimulations were removed during the hatching process and the days after, a circadian rhythm in the evolution of the noise was found. This illustrates the hypothesis of Willbold et al. (2002) that the pacemakers for circadian rhythm impose their own internal rhythm.

TABLE 2. Time points of the start and the maximal height of each noise cycle compared with the natural day-night cycle

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Cycle 1</th>
<th>Cycle 2</th>
<th>Cycle 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1415</td>
<td>1148</td>
<td>1147</td>
</tr>
<tr>
<td>Maximal noise (h)</td>
<td>0112</td>
<td>0012</td>
<td>0000</td>
</tr>
<tr>
<td>2</td>
<td>1057</td>
<td>0818</td>
<td>0554</td>
</tr>
<tr>
<td>Maximal noise (h)</td>
<td>2145</td>
<td>1621</td>
<td>1421</td>
</tr>
<tr>
<td>3</td>
<td>1448</td>
<td>1306</td>
<td>0948</td>
</tr>
<tr>
<td>Maximal noise (h)</td>
<td>2318</td>
<td>2330</td>
<td>0018</td>
</tr>
</tbody>
</table>

ABBREVIATIONS

Acknowledgments

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