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Research paper

Prediction of chick hatching time using visible transmission spectroscopy combined with partial least squares regression

Md. Hamidul Islam [a, *], Naoshi Kondo [a], Yuichi Ogawa [a], Tateshi Fujiura [a], Tetsuhito Suzuki [a], Shusaku Nakajima [a], Shinichi Fujitani [b]

[a] Graduate School of Agriculture, Kyoto University, Kitashirakawa-Oiwakecho, Sakyo-ku, Kyoto 606-8502, Japan
[b] NABEL Co. Ltd., 86 Morimotocho, Nishikujo, Minami-ku, Kyoto 606-8444, Japan

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ABSTRACT

The feasibility of using visible transmission spectroscopy for the prediction of chick hatching time was investigated. An experiment was conducted with 100 chicken eggs in which transmission spectra were measured between incubation day 0 (non-incubated) and days 8 and subsequent hatching time was recorded. Spectral transmittance in the range of 500–750 nm was used in analysis. Spectral data were linked to hatching time using a partial least squares (PLS) regression method. Different pre-processing procedures were compared. The calibration model using incubation day 4 spectra with multiplicative scatter correction (MSC) resulted in the lowest root mean square error of prediction (RMSEP) = 3.41 h. The result indicates that the use of visible transmission spectroscopy combined with multivariate analysis has potential to predict the chick hatching time.

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1. Introduction

Day-old chicks are an important starting input for broiler farms, and the end product of the poultry hatchery. Overall success in broiler production depends on the quality of these chicks. The quality of day-old chicks is determined from their post-hatched survivability and growth potential, i.e. growth rate, breast meat yield and feed conversion ratio (Decuypere and Bruggeman, 2007).

For broiler farmers, the aim is to obtain a batch of homogeneous, high quality chicks. However a batch of day-old chicks is frequently not homogeneous in quality due to the spread of the hatch window (Tona et al., 2003). Ideally, all chicks in a batch are desired to hatch at the same time, but in reality, chicks hatch at different moments within a time period called the “hatch window”. As a result of this broad hatch window, a production manager is dealing with chicks of different biological ages at take-off.

Though the chronological ages of the chicks in a batch are defined by convention as being the same, the earlier hatched chicks are in reality older than one day. These chicks often show signs of dehydration at takeoff and are a poor quality stock for later production. In addition, the delay in the collection of the chick batch also delays further hatchery procedures, such as sexing, vaccinations, packaging, and transportation, which also ultimately delays the first feed and access to water.

Previous researchers have reported that the delay in the feed intake is associated with higher early mortality in chicks and impaired performance throughout the growth period (Chou et al., 2004; Gonzales et al., 2003). Therefore, a narrow hatch window is desired by poultry hatchery managers in order to produce the best quality chicks. However, it is very difficult for the hatchery managers to correctly estimate hatching time and consequently the spread of the hatch window. This is because the hatching time of individual chicks within a batch is influenced by multiple factors, such as the age of parent flock, egg handling, egg storage duration, and incubation conditions (Decuypere et al., 2001).

Since a narrow hatch window results in higher quality chicks due to the smaller variation in the biological ages of chicks, hatchery managers undertake several techniques in order to obtain a narrow hatch window. The most common method used is to collect chicks that hatch in the first 24 h window. The main drawback of this method is, if the incubation is ended prematurely, eggs with viable chicks inside them are thrown away, decreasing the hatchability of the cohort and resulting in economic losses. Other techniques to optimize hatchability include exchanging the

* Corresponding author.
E-mail address: hamidfpm@bau.edu.bd (Md.H. Islam).

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position of the egg trays from cold to hot areas inside of the incubator and vice versa, increasing either temperature or carbon-dioxide (CO_2) levels in the hatcher, as reviewed by Hill (2011). These practices can improve the hatchability of chicks to some extent, but cannot produce the best quality chick cohort, because individual chicks have their own natural hatch window and a short hatch window created by overheating the embryos or increasing CO_2 level in the hatcher is not a natural hatch window. Therefore, development of a new hatch window control technique is demanded by the poultry hatchery in order to obtain the best quality chicks with high hatchability.

Hatching time of chicks is closely related to embryonic development. The incubation length required by an egg is predetermined by this embryonic development. In fertile hatching eggs blood formation takes place from day 2 of incubation, as reviewed by Bamelis et al. (2002), and subsequent physiological changes occur in live embryos during the incubation period. Thus information about the stage of embryonic development could be used to estimate the incubation length needed by the egg to hatch.

Nowadays, spectral measurements are commonly used to extract internal information about eggs, such as blood and meat spots, presence of embryo, embryonic growth, and egg freshness. Such spectral measurements have the advantage of being fast, nondestructive, and noncontact. Moreover, this technique can be implemented at a reasonable price. Preliminary investigations have revealed that significant variations in the spectra were found during incubation. Kemps et al. (2010) used visible transmission spectroscopy coupled with a multivariate analysis technique to assess embryonic weight in chicken eggs. They linked spectral information to embryonic weight using a partial least square (PLS) regression method and reported correlation coefficients of 0.97 based on the multiplicative scatter correction (MSC) spectra for the prediction of embryonic weight within the spectral range 570–750 nm. To our knowledge, however, no attempts have been made to estimate the hatching time of chicks using spectral information.

The goal of this study is to investigate the potential to predict hatching time of chicks using visible transmission spectroscopy combined with an appropriate multivariate analysis method. A partial least square (PLS) regression algorithm was employed to build a calibration model for the prediction of hatching time of chicks. Spectral information in the range 500–750 nm was used to develop a calibration model.

2. Material and methods

2.1. Material

A total of 100 light brown-shell chicken eggs laid by a commercial broiler breed (Ross 308 strain) were used in this study. All eggs were collected from a commercial poultry hatchery (Yamamoto Co. Ltd., Kameoka, Kyoto, Japan). At the moment of egg collection, the laying hens were 36 weeks of age. Since large variation in the size of eggs effects on hatching time, all samples were selected within a range of 42.5–44.5 mm (diameter), 54.4–59.4 mm (height) and 55.5–65.5 g (weight) to minimize their effects. In addition, to minimize the effect of egg shell pigmentation on transmission spectra, eggs with nearly similar shell color (selected by color image analysis method) were selected. Prior to incubation, all eggs were stored for 3 days following standard poultry hatchery practice (at 15.0 (±0.5) °C and 80 (±5) % of relative humidity (RH)).

2.2. Spectral acquisition system

The experimental setup used for the measurement of the transmission spectra of an intact egg is shown in Fig. 1. The egg is positioned vertically in a plastic holder with the blunt end pointed upward between the illuminating fiber and the collecting optical fiber. The illuminating fiber was used for cool illumination of the eggs and the optical fiber was used to collect and transport the transmitted light to a Hamamatsu C 7473-36 model spectrometer (Hamamatsu Photonics K. K, Japan). The distance between the illuminating fiber and the optical fiber was kept at 100 mm to obtain a consistent transmission signal. A halogen light source (FHL-10, Asahi Spectra Co. Ltd., Japan) was used for illuminating the samples. This light source consisted of a dichroic reflector type halogen lamp (capable of cutting off infrared energy) in order to prevent warming of the egg surface where the light beam is shone onto the eggshell. The light was focused on the egg surface by an illuminating fiber of 5 mm in diameter and only the light that transmitted through the egg was received and transported by the optical fiber (1 mm effective light receiving diameter) to the spectrometer. The software package PMA-11 Spectral Analyzer for Windows (PMA Software U6039-01, Hamamatsu Photonics K.K., Japan) was used to control the spectral acquisition process.

The transmission spectra of the eggs were measured over the spectral range of 200–950 nm at 1 nm intervals. The integration time for one scan was 100 ms and the spectrum of each egg contains an average of 10 scans. Since the characteristics of a halogen lamp changes over time, the spectrometer was calibrated before each measurement using a Teflon block (PTFE push rod Ø45 mm, Chukoh Chemical Industries, Ltd., Japan) of 30 mm thickness (Kemps et al., 2010). In addition, the reference spectra were measured after each 10 samples to evaluate any changes in the reference spectra with time. Furthermore, a correction was made for the electrical noise by taking the spectra with no light exposure to the spectrometer. All measurements were done inside a black box to shield any stray light from entering. The transmission values of light passing through an egg are expressed as a ratio of the amount of light passing through the eggs to the amount of light passing through the reference at the same wavelength (Kemps et al., 2006). The relative transmission (T) was calculated using Eq. (1).

$$T(\lambda) = \frac{S(\lambda)}{R(\lambda)} \quad (1)$$

Where:

$T(\lambda)$ is relative transmission at wavelength λ nm
$S(\lambda)$ is intensity of sample at wavelength λ nm
$R(\lambda)$ is intensity of Teflon reference at wavelength λ nm

It should be noted that the term “transmission spectra” used throughout this text refers to the relative transmission spectra.

2.3. Experimental design

Prior to setting the eggs into the incubator, eggs were preheated for 16 h (first 6 h at 28 °C and the remaining 10 h at 30 °C) to bring the embryos to a uniform temperature when they are placed into the incubator. Just prior to incubation (referred to as “Day 0”), the transmission spectra of all eggs were measured. Upon completion of measurements, the eggs were immediately placed in a commercial incubator (SSH-02 all in one type, Showa Furanki Co. Ltd., Saitama, Japan) to incubate at 37.8 °C and 55% of relative humidity according to Lourens et al. (2005). During incubation eggs were turned automatically every hour through an angle of 90° until incubation day 18. Between incubation day 1 to day 8, eggs were taken out from the incubator every 24 h to measure the spectral transmission of each egg. To minimize exposure time of the egg

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