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The sensor to estimate the sound pressure level in eggs

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ABSTRACT

Before assessing the effects of sound stimuli on the embryonic development of poultry, the current study asked the following question: what sound pressure level (SPL) would embryos inside eggs be exposed to? The question has motivated the current research, which developed a reduced-size sensor (miniaturized decibel meter) to help measuring SPL inside artificially-incubated eggs (microenvironments). The sensor was developed by using the Arduino® microprocessor - a standard amplifier circuit and electret microphones. Calibrations were performed in a commercial decibel meter to allow confirming the sensor capacity. However, it was necessary using mathematical models to help converting the sound measures to the decibel scale, since the direct conversion of them was not possible. The use of the sensor in studies focused on artificial incubation confirmed the acoustic insulation capacity of eggshells. However, results showed that the internal SPL (air chamber) in eggs externally exposed to 90 dB (A) remains high and probably perceptible to embryos. Such information is highly relevant to studies focused on investigating bioacoustics during incubation.

1. Introduction

Bioacoustics and sound analysis emerged as a new research field in poultry production in order to optimize the conditions of the rearing environment (Ben Sassi et al., 2016). For example, sound technologies are used for monitoring feeding behaviors of broiler chickens (Aydin et al., 2015; Aydin and Berckmans, 2016); to determine the adequacy of the thermal environment (Moura et al., 2008) and in the artificial incubation process, which is the focus of this research.

Artificial incubators have sufficient technology such as ventilation, egg turning, humidity and refrigeration systems to assure optimal poultry-embryo development conditions. However, noise is inevitable during such procedures, since engines and fans are constantly working, which results in sound pressure levels exceeding 95 dB (A) (Carvalho et al., 2015).

Accordingly, studies have demonstrated distinct aspects of the effect of sound (rhythmic music, species-specific vocalizations and random noises) on the embryonic development of birds, such as changes in responses associated with the maturation of physiological systems and even with the post-hatching life (Alladi et al., 2005; Kesar, 2013; Sanyal et al., 2013; Tong et al., 2015). However, it is necessary investigating some issues in the case of embryos exposed to external sounds. One of these issues lies on the embryonic functionality of the avian auditory system, which was already proven by Jones et al. (2006). Another issue refers to sound wave absorption and transmission by egg constituents, which was only investigated in preliminary studies, so far. Information about the acoustic parameters inside the incubated eggs is not easily found. For instance, we need to know the sound intensity near the embryo to establish critical exposure values.

Sound is a longitudinal wave that leads to pressure variations in different media such as air, water or solids. The sound pressure level (SPLS) represents the volume auditory perception, whose measuring device is known as decibel meter. According to David et al. (2013), decibel meters are electroacoustic transducers capable of detecting sound and of converting it into an electrical signal, as well as of amplifying and processing it. According to the international standard IEC 61672-1 (2002), such equipment presents many variations, which directly affect its efficiency, accuracy and cost.

Thus, the current study developed a sensor by using the Arduino® platform, which is an open-source microcontroller that presents a range of applications when it is associated with different sensor modules and actuators (Hjort and Holmberg, 2015; Torres et al., 2015). Arduino® was launched in 2005 as an easy-to-apply platform for programming beginners (Haugen and Moore, 2014). According to D'Ausilio (2012), this microcontroller allows using multiple hardware complements and free scripts for different purposes.

After its popularization, Arduino® started being used to develop sensors, fact that made it easily applicable to measure temperature,

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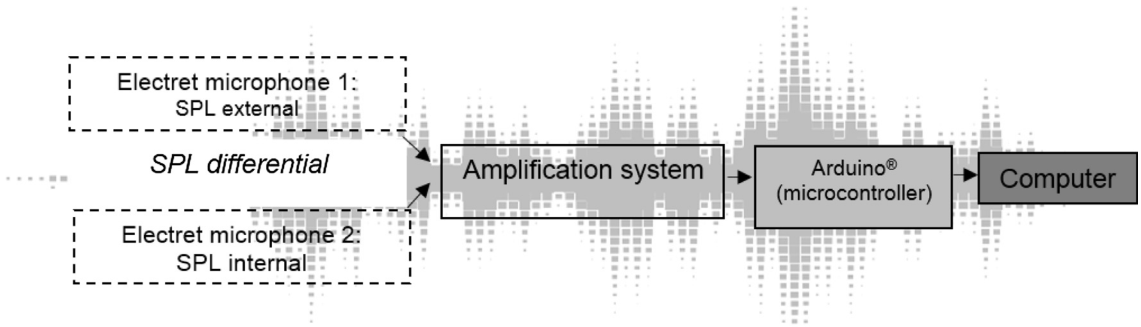


Fig. 1. Organogram of the sensor-development project.

luminosity and radiation, relative humidity (Fernandes, 2015; Torres et al., 2015; Jordão et al., 2017; Oates et al., 2017), mechanical vibration (Hjort and Holmberg, 2015; Jaber and Bicker, 2015) and sound pressure levels (Feitosa et al., 2014; Quintana-Suárez et al., 2017). Arduino® is an efficient tool for the measurements, although adaptations are required.

The aim of the current study was to develop, calibrate and test a sensor to help estimating sound pressure levels in microenvironments, such as inside fertile eggs, to gather information about the acoustic insulation capacity of eggshells in researches with bioacoustics in artificial incubation.

2. Materials and methods

2.1. Sensor development

The sensor herein developed to measure sound pressure levels (SPL) resulted from the need of using a reduced-size equipment to estimate to what extent sounds would be perceived by embryos inside eggs. The project is shown in Fig. 1.

The Arduino® UNO R3 was used as microcontroller. This model is based on the Atmega 328P processor, which presents six input and six output channels that allow connecting several electronic components programmed for and directed to a particular function. Two electret microphones (0.5 cm diameter), Mic 1 and Mic 2, were used to simultaneously measure the sound pressure level in two distinct environments: inside and outside eggs. Overall, microphones respond to sound intensity variations through vibrations in their internal membranes, which transform the sound into an electrical signal. However, it is necessary adopting an amplifier system because this signal is low. Thus, an amplification system with two 100 nf capacitors, four 10 k resistors, two 500 k trinpots and two BC 548 transistors was herein assembled. Details on the final version of it can be found in Fig. 2A.

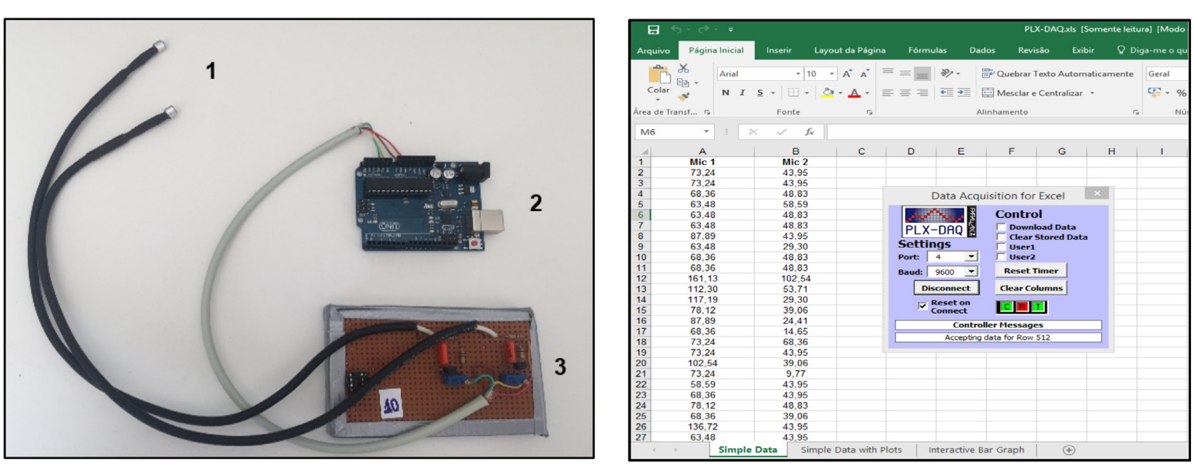
The herein developed sensor was directly connected to the USB port of a computer to enable data acquisition. The programming in C language was done in an open-source processing environment. Parallax Data Acquisition tool (PLX-DAQ®) was used to directly insert data into a Microsoft Excel® spreadsheet, whose output is shown in Fig. 2B (Dworakowski et al., 2016).

2.2. Calibrating and converting the electrical signals of the sensor

Calibration was performed based on Feitosa et al. (2014) and Fernandes (2015). The sensor was compared to commercial equipment in a sequence of tests focused on investigating its responsiveness to variations in the ambient SPL by comparing the herein collected data to those recorded in a duly-calibrated Instrutherm® decibel meter, model DEC - 490. The use of the decibel meter was programmed for "A" weighting, with automatic collection (30–130 dB range) and "slow" mode; records were made every second.

A white noise (100–15000 Hz) was emitted by an amplifier box (Mini Speaker® - BT51) of nominal power 15 W, which was previously calibrated in different volume configurations, according to SPL values set by the commercial decibel meter. The sensor microphones were placed parallel to the microphone of the commercial decibel meter, ten centimeters away from the sound source. The system was initially tested under silent condition. Next, the amplifier box volume was gradually increased (settings: 0, 5, 10, 15, 20, 25 and 30). Five sets of tests were conducted, in total; each set lasted one minute at each volume.

Data collected by the miniaturized decibel meter were electrical signals obtained at rate of ten values per second. Thus, the means of



A B

Fig. 2. Sensor developed in the current study: (1) microphones, (2) amplifier circuit, (3) Arduino® board (A); PLX-DAQ® tool used to collect data (B).