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A novel method to automatically measure the feed intake of broiler chickens by sound technology

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ABSTRACT

This paper proposes a novel method to automatically measure the feed intake quantity of broiler chickens by sound technology. In this research, an algorithm was developed to detect individual pecking sounds of broiler chickens. Afterwards, the relation between pecking sounds and the amount of feed intake was investigated. The results of the algorithm were compared to reference feed intake values obtained through weighing scale measurements and video observations. The pecking sounds of 12 individual, 28 days old, male broiler chickens (Ross-308) were recorded during 15 min in three consecutive days by a microphone that was attached to the feeding pen. Three laboratory experiments were conducted with each broiler resulting in a total of 36 experiments. Each chicken was deprived from food for four hours prior the experiment. During experiments, feed uptake quantity was automatically recorded using a weighing system. Feed wastage of chicken was manually collected and weighed after each experiment. Based on the measurements of feed uptake and feed wastage, the feed intake of broilers was calculated and used for the validation of the proposed algorithm. The results show that 93% of the pecking sounds were correctly identified by algorithm, whereas 7% of the identification results were false positives. In addition to pecking sound identification the relation among feed uptake, feed intake and number of peckings was calculated. A linear relation was found among these three variables. A linear regression test was performed to define the coefficient of determination between the number of peckings and the amount of feed uptake of chickens, which resulted in (R^2 = 0.995). Furthermore, the relation between the amount of feed intake and the number of peckings (pecking frequency) was investigated and the coefficient of determination R^2 was 0.985. In addition to the high relation, 90% of feed intake was correctly monitored using sound analysis.

Since the correlation between the number of peckings and the amount of feed intake of chickens was very high (R^2 = 0.985) the results suggest that this pecking sound detection system has potential to be used as a tool to monitor the feed intake of chickens. The advantage of this system is that measurements can be made continuously throughout the life span of a flock, in a fully automated, completely non-invasive and non-intrusive way.

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1. Introduction

The need for livestock monitoring and the integration of animal responses in livestock farming has been reviewed by Frost et al. (1997) and Aerts et al. (2003). In recent years the analysis of farm animal vocalisation has gained increasing interest and a variety of attempts to decode the meaning have been made (Manteuffel et al., 2004). For example, Enting et al. (2000) described a knowledge-integrated computer system to support health management in pig farms. Other approaches examined the relationship between vocalisation, (Van Hirtum and Berckmans, 2004; Exadaktylos et al., 2008a) drinking behaviour (Madsen and Kristensen, 2005) or temperature (Geers et al., 1997) and pig health (Silva et al., 2008; Ferrari et al., 2008; Guarino et al., 2008; Exadaktylos et al., 2008b). Beside pig vocalisations there have also been extensive researches on poultry behaviour and welfare related to sound vocalisation (Zimmerman et al., 2000a,b; Evans and Evans, 1999). The question of how poultry behaviour and/or well-being may be influenced by management or environmental stimuli. Researchers are trying to investigate which responses should be measured and whether bird responses are correlated to well-being. One means of assessing bird responses to stimuli involves careful analysis of individual or group characteristics over time. Monitoring individual behaviour during research trials is typically performed using a type of video imaging system. For poultry, behavioural activities

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are categorized into events such as eating, drinking, preening, resting, and stereotyped activities directed at different targets. This assessment methodology is time-consuming, hence costly, tedious and prone to errors, even with modern commercially available research systems that compile the statistics semi-autonomously. Therefore, there is an increasing need for means to further automate collection of event-based behavioural responses (Gates et al., 1995; Gates and Xin, 2001; Persyn et al., 2004; Xin et al., 1993). For this purpose, computer and modern electronic technologies have been applied to monitor bird feed intake, body weight and feed conversation ratio (FCR) (Hulsey and Martin, 1991; Xin et al., 1993; Yo et al., 1997; Savory and Mann, 1999; Puma et al., 2001). For example, algorithms for determining individual bird feeding statistics and stereotyped pecking behaviour from time-series recordings of feed weight were developed and compared to video observations by Gates and Xin (2008). In another study, focussing on turkey breeding, a structured query language (SQL) database management system was developed by Xuyong et al. (2011) to record and manage the dynamic feed intake and body weight gain data of individual birds. However, up to now, the same methodology has been applied by defining poultry feed intake based on weighing scale data. For example, the feeding pattern of broiler chickens was investigated by Kutlu and Forbes (2000) using the continuous recording of feeder weight. At the same time, sound recording as a different method started to be used for calculation of the feed intake of different animal species (Laca and WallisDeVries, 2000; Milone et al., 2009, 2012). For instance, Laca and WallisDeVries (2000) studied acoustic measurements of feed intake and grazing behaviour of cattle by attaching three microphones on each animal.

In this research, a novel method is investigated by using a sound detection system to calculate the feed uptake and feed intake of broiler chickens. In contrast to previous studies, this is the first time that a sound detection system was implemented in the feeder instead of a device attached on each animal. A major advantage of this sound detection system is that the measurements can be made continuously throughout the life span of a flock, in a fully automated, completely non-invasive and non-intrusive way.

The objectives of this research are: (1) to test, develop and validate an algorithm for detection of individual bird pecking sounds and (2) to obtain a novel method for estimating absolute amount of feed uptake, feed wastage and feed intake of broiler chickens.

2. Materials and methods

2.1. Experimental setup

The recordings were carried out with 12 broiler chickens during three consecutive days. Three experiments were conducted with each broiler for a total of 36 experiments.

Each single chicken was housed in a different cage without access to feed and water for four hours before the experiment in order to stimulate pecking at the onset of the experiment. Each experiment lasted for 15 min. During the experiment an individual bird was placed in a separate cage (50 × 50 × 50 cm). The pecking sounds of broiler chickens were generated by the beak touching and dipping into the feed (Grower Pellets) on the feeder. These generated sounds were continuously recorded and analyzed. Besides, other sounds such as vocalisation and environmental sounds were also continuously recorded. At the same time, video images were captured and feed uptake of the chicken was continuously recorded (sampling frequency of 10 Hz) by a weighing system, which was connected to the PC via RS-232 cable. After recording of all data, sound data were analysed by a pecking detection algorithm in MATLAB® (Mathworks). For validation of the proposed algorithm, chicken peckings in the image data were manually labelled using the labelling tool developed by Leroy et al. (2005). A second validation was based on the measured weighing data was used. For the sound recording, an electrets microphone (Monacor ECM 3005) was positioned under and attached to the bottom of the feeding pan (Fig. 1). The microphone had a frequency response of 30–20,000 Hz and was connected to PC via preamplifier (Monacor SPR-6). All recordings were sampled at a 44.1 kHz with a 16 bit resolution. For the video recordings, an USB webcam (Logitech Webcam Pro 9000) with 3.7 mm Carl Zeiss® lens mounted next to the cage at 50 cm distance and with its lens pointing towards the cage to get a side view of the feeder (Fig. 1).

Images were captured with a resolution of 640 horizontal by 480 vertical pixels at a sample rate of 15 frames per second. During the video recordings, light was kept on at 10 lux. The feeding pan was placed on a precision balance (KERN PCB-250-3, with weighing range 250 g and accuracy 0.001 g).

2.2. Birds and housing

Experiments were carried out with 28 day old, 12 male, Ross 308 broilers. Animals were vaccinated, following standard procedure, both at the hatchery and in the stables on day 23. For the first nine days, a pre-starter diet with 23% protein and 2890 kcal Amen/kg (apparent metabolisable energy) was given. From day 10 to day 13, a starter diet with 22% protein and 2794 kcal Amen/kg, and from day 14 to day 32, grower diet with 20% protein and 2899 kcal Amen/kg, were provided.

Birds were transported to the laboratory in two hours from a local farm (Provincial Center for Applied Poultry Research, Geel, Belgium). Birds were kept in floor pens 0.5 × 0.5 × 0.5 m with wood shavings. Feed and water were freely available to birds during the experiments.

2.3. Pre-processing of sound signal

2.3.1. Definition of frequency ranges

Before sound extraction was applied, recorded data were pre-processed to define the best frequency differences between the pecking and other sounds. Afterwards, the individual sounds (pecking and other sounds) were manually extracted from the continuous recordings and stored as individual sounds. The resulting data set of 100 individual pecking sounds and 100 other sounds was used to define the best frequency differences between the pecking and other sounds.

2.3.2. Filtering

To eliminate low frequency noise produced mainly by the ventilation system in the laboratory, the signal was initially band pass-filtered (6th order Butterworth filter) with cut-off frequencies of 1000 Hz and 5000 kHz (Fig. 2).

The pecking sound signals needed to be recognised were not affected by this filter since they had considerable low frequency components and the frequency range between 1000 Hz and 5000 Hz held enough information for the purpose of this study.

Fig. 2 shows filtered sound signal between 1000 Hz and 5000 Hz.

To reduce processing time of the algorithm, the sound signal was down sampled from 44,100 to 11,025 Hz. The flowchart for the proposed signal processing procedure is shown in Fig. 3.

2.4. Sound extraction

The algorithm was composed of two major parts: first, the individual sounds were extracted from a continuous recording, and

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