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Image analysis method to evaluate beak and head motion of broiler chickens during feeding

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ABSTRACT

While feeding broiler chickens may exhibit different biomechanical movements in relation to the physical properties of feed such as size, shape and hardness. Furthermore, the chicken's anatomical features at various ages, genders and breeds in conjunction with feed type and feeder design parameters may also have an influence on biomechanical movement. To determine the significance of these parameters during feeding, kinematic measurements related to the biomechanical motions are required. However, determining this information manually from video by a human operator is tedious and prone to errors. The aim of this study was to develop a machine vision technique which visually identifies the relevant biomechanical variables attributed to broiler feeding behaviour from high-speed video footages. A total of 369 frames from three broiler chicks of 5 days old were manually measured and compared to the automatic measurement. For each bird six mandibulations (i.e. a cycle of opening and closing the beak) were manually selected, which were two different sequences of three consecutive mandibulations starting right after a feed grasping. The kinematics variables considered were: (i) head displacement (eye centre position; *x*- and *y*-axis); (ii) beak opening speed (given in mm ms^{-1}); (iii) beak closing speed (measured in mm ms^{-1}); (iv) beak opening acceleration (given in mm ms^{-2}); and (v) beak closing acceleration (given in mm ms^{-2}). Results indicated that the highest error for eye position detection was 1.05 mm for *x*-axis and 0.67 for the *y*-axis. The difference between manual and automatic (algorithm output) measurements for the beak gape was 0.22 ± 0.009 mm, in which the maximum difference was 0.76 mm. Regression analysis indicated that both measures are highly correlated (R^2 = 99.2%). Statistical tests suggested that the primary probably causes of error are the speed and acceleration of the beak motion (i.e. blurred image), as well as the presence of feed particles in the first and second mandibulations right after the feed grasping (i.e. occluded beak tips by feed particles). The presented method calculated automatically the position of the eye centre (*x*- and *y*-axis) and both upper and lower beak tips distance in a high level of accuracy, but the model can be improved by using a camera with higher resolution, a higher acquisition rate, and infrared-reflective markers. The method has the potential to facilitate efficient and repeatable acquisition of biomechanical data of broiler chickens during feeding, and be used to benchmark the feed physical properties and its processing methods, likewise evolving knowledge for futures studies in feeders' design.

1. Introduction

The poultry industry is considered as one of the most active meat producing industries requiring frequent increases in production to satisfy the worldwide demand for poultry meat. The largest broiler chicken producers by country are the United States, China and Brazil with the United States and Brazil contributing to two-thirds of poultry meat exports globally (FAO, 2012; USDA, 2012). Feed costs are the main drivers of profitability on commercial poultry farms, so minimizing feed wastage is desirable. Advances in poultry nutrition are mainly responsible for the exceptional growth rate responses of current domesticated species. In addition to nutritional value, the feed properties should also ensure it is palatable and easy to consume and digest by the birds.

Past research have investigated the impact of both chemical and physical characteristics of the feed on animal responses, and the economic feasibility regarding feed processing methods (Thomas et al., 1998; Perez and Oliva-Teles, 2002), feed particle size (Nir et al.,

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1994a; Amerah et al., 2007), feed material form (Greenwood et al., 2004; Nir et al., 1994b; Skinner-Noble et al., 2005; Zang et al., 2009), and more recently the influence of feeders' features on birds' preferences (Neves et al., 2010; Roll et al., 2010). To date, the scientific research on broilers' feeding performance and behaviour are based on productivity indexes, physiological responses and the impact of environmental conditions. However, little is known about the biomechanical responses of birds during feed consumption.

Biomechanics can be described as a physical (mechanical) movement displayed or produced by living systems (Mclester and Pierre, 2008). Studies in biomechanics are of interest to various professional fields, such as zoology, medical, biomedical engineering, and kinesiology (study of human movement) (Hall, 1999). The detection of jaw movement has been previously examined by identifying features that characterize prey ingestion in captive animal species of mammals (Ropert-Coudert et al., 2004), birds (Van Der Heuvel and Berkhoudt, 1998), fishes (Wainwright, 1991), carnivorous and herbivorous feeding habits and either marine or terrestrial environments were investigated (Pennycuick, 1992). Furthermore, Stefen et al. (2011) used the digital bi-planar high-speed X-ray system to investigate jaw movements during incisor action and mastication in beaver.

The mechanical process exhibited by domestic chicken while feeding is similar to that of pigeons and can be divided into different phases starting with the identification of a potential feed particle and ending with ingestion. Terminology for the various stages exhibited includes fixation, approach or pecking, grasping, withdrawal, stationing, transporting, collecting and swallowing (Zweers, 1982; Bermejo et al., 1989; Van Der Heuvel and Berkhoudt, 1998). These phases are described according to the position of the feed within the beak, and the motion and position of the particular parts of the chicken's body during the eating process (head height, upper and lower beak displacement, sliding movement of the tongue and the eye blink). Furthermore, the feeding behaviour of these birds was described as stereotyped movement patterns, considering both duration and temporal organization of the variables involved the process (Zweers, 1982; Van Der Heuvel and Berkhoudt, 1998). The bird can adapt certain movement patterns depending on the type of feed, but such behaviours are subordinate to limitations of morphological structure and mechanical construction (Zweers, 1982).

Most research on broiler feeding behaviour addresses the productivity indices and birds' physiological responses. This paper aims to present a methodology to evaluate the biomechanical motion of broiler chickens while feeding through computational image analysis, considering the movement characteristics of the birds' beak and head.

2. Material and methods

2.1. Birds and facilities

The experiment was carried out at the Construction and Environmental Laboratory in the Agricultural Engineering College (FEAGRI), the State University of Campinas (UNICAMP), Campinas-SP, Brazil, in July of 2011. For the present study, three male broiler chicks (Cobb® strain) of 5 days old were randomly chosen from a climate chamber of another experiment, which standard broiler housing was adopted (Cobb-Vantress, 2009). At this stage of the present study, the use of three specimens seems to be enough to present the proposed methodology, in accordance with previous studies approaching kinematic analysis of fishes (Tran et al., 2010; Wassenbergh and Rechter, 2011), turtles (Natchev et al., 2009), lizards (Schaerlaeken et al., 2007), and birds (Gussekloo and Bout, 2005; Dawson et al., 2011).

2.2. Experimental procedure

The broiler chicks were placed individually in a rectangular glass box containing a feed tray. For birds 1 and 2, it was offered mash-type ration and for bird 3 grinded corn. A high-speed camera (Mikrotron EoSens®, Mikrotron GmbH, Unterschleißheim, Bavaria, Germany) with Nikon lens 50 mm/F 1.4 was set up with an acquisition rate of 300 fps (frames per second) and used to record the birds' feeding behaviour. This acquisition rate resulted in 3 ms (ms) time delay between frames. With the aid of a tripod, the camera was positioned to fit the bird's head and the feed tray in a perpendicular-lateral direction, in the field of view of the camera. A white paper sheet was placed in the background, to provide better contrast between the bird and its surrounds (Estrella and Masero, 2007). The high-speed camera was connected to a personal computer to store and manage the data. The trials occurred outdoor during a short period, so no artificial light source was used, since the natural daylight with small variations was capable of illuminating the scene.

2.3. Frames sequences classification and kinematic variables

The analysed frames sequences were first selected and classified manually. For each one of the three birds, it was considered six mandibulations, which were two different sequences of three consecutive mandibulations starting right after the feed grasping (Fig. 1; Table 1). The mandibulation consisted of a cycle of opening and closing the beak, in which the beak in the first opening frame and the last closing frame was not necessary completely closed. The chosen mandibulations sequences were those which the head remained in a perpendicular lateral orientation to the camera view.

The kinematic variables analysed were: (i) head displacement (eye centre position; x- and y-axis); (ii) beak opening speed (given in mm ms^{-1}); (iii) beak closing speed (given in mm ms^{-1}); (iv) beak opening acceleration (given in mm ms^{-2}); and (v) beak closing acceleration (given in mm ms^{-2}). Displacement is defined as the change in position (expressed in mm). Speed is the time derivative of displacement, which is the rate of change of displacement regarding time (given in mm ms^{-1}). Acceleration is the time derivative of speed, which is the change of velocity with respect to the time (expressed in mm ms^{-2}) (Robertson and Caldwell, 2004). The feed tray diameter (47 mm) was used for calibration.

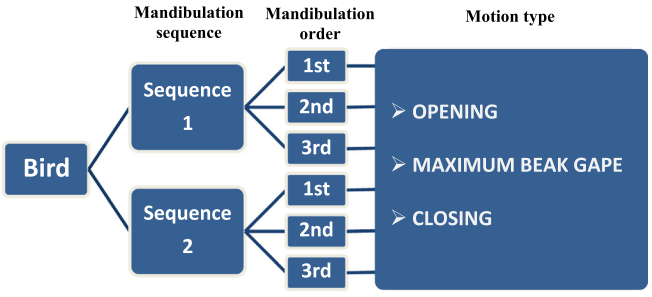

Fig. 1. Schematic representation of frames sequences classification for one bird.

Table 1
Number of analysed frames by birds, mandibulation order, and motion type.

Bird	Frames	Mandibulation	Frames	Motion type	Frames
1	130	1st	68	Opening	224
2	141	2nd	143	Maximum beak gape	18
3	98	3rd	158	Closing	127
Total	369	–	369	–	369