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Technical note: Evaluation of a new system for measuring feeding behavior of dairy cows

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ABSTRACT

Feed intake, feeding and rumination time are important parameters in the identification of suboptimal feeding conditions and possible health disorders. The automatic recording of individual feeding behavior constitutes a reasonable tool for early detection of deviations in feeding behavior and feeding deficiencies. For this reason, a new system for measuring feeding behavior of dairy cows has been developed. The sensor-based system DairyCheck consists of a halter with two incorporated electrodes, a data logger, an accelerometer, power supply, and evaluation software. Measurement of feeding behavior ensues through surface electromyography (EMG), whereby electrical potential oscillations during jaw movements are recorded. Data are transmitted directly via radio transmission to a computer with automatic evaluation software. Automatic analysis software is based on an algorithm to identify single jaw movements and differentiate between active feeding phases and non-active dormant phases. For validation, feeding behavior of 14 cows as determined by both the EMG system and visual observation was analyzed. Results showed adequate agreement of the results of both assessments. However, further progress and research are necessary for automatic data interpretation with a self-learning algorithm, to develop this EMG-based system into an appropriate management tool in the field of precision dairy farming.

1. Introduction

Increased milk performance per cow requires raised proportions of concentrate and energy (Krause and Combs, 2003) to compensate for limited physiological feed intake capacity (Allen, 1996; Grant and Albright, 2001; Harvatine and Allen, 2006). This practice results in feeding diets that are relatively low in dietary fiber and adequate particle size (Beauchemin et al., 2003; Beauchemin and Yang, 2005), thereby impairing optimal conditions for microbial activity in the rumen. Consequently, there may be disturbances of fermentation and of rumen activity as well as decreased feed intake, all of which can lead to subclinical and clinical metabolic disorders (Nocek, 1997; Maekawa et al., 2002). A well-adapted energy supply according to the individual requirements and an appropriate amount of fiber content in the diet are immensely important for the health, performance and reproduction of ruminants (Beauchemin and Yang, 2005; Zebeli et al., 2008).

The diurnal surveillance of feeding behavior, which is characterized by feed intake, feeding time (FT) and rumination time (RT) is essential with regard to its potential as an indicator of suboptimal feeding conditions and as a parameter to assess and construct feeding rations (Owens et al., 1998; Urton et al., 2005; De Vries et al., 2009). The daily observation and ascertainment of the feeding behavior of ruminants constitutes an obvious tool for monitoring health status (Hansen et al., 2003), considering the feeding situation of the whole herd as well as that of individual animals. However, the measurement systems available for monitoring feeding behavior do not meet all requirements for the optimal observation of cow feeding behavior.

Reviewing the past progress, there exist various measurement devices with different stages of development and practical usage with variable reliability. They can be divided into five measurement methods basing on different methodological approaches. The method of visual observance determines the chewing and rumination activities of ruminants through counting by human observers (Erlinger et al., 1990; Burfeind et al., 2011), which is a suitable and valid method (Schirmann et al., 2009), but labor-intensive and time-consuming (Mosley et al., 1987; Matsui and Okubo, 1991; Mitlöhner et al., 2001; DeVries et al., 2003). Pressure transducers are based on hydraulic or pneumatic processes. With this sensor method a pressure typist is mounted beneath the animal's muzzle and consists of a liquid- or air-filled plastic ball or

Abbreviations: EMG, electromyography; FT, feeding time; RT, rumination time.

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plastic tube (Deswysen and Ellis, 1990; De Boever et al., 1993). Each pressure alteration corresponds to a deflection on the analog output in terms of graphs, whereby exact allocation into chewing, rumination or other behaviors is possible. Till recently (Zehner et al., 2012), this method was restricted only to animals housed in metabolism crates or in tie-stalls (Schleisner et al., 1999). During the method of electrical switches the switch, which is attached to a halter and placed under the jaw, is activated by jaw movements of the animal (Law and Sudweeks, 1975; Nagel et al., 1975; Luginbuhl et al., 1987). The individual jaw movements are transformed into binary notations. Electrical deformation sensors are another alternative means of measuring the chewing and rumination behavior of dairy cows (Penning, 1983; Beauchemin et al., 1989). These sensors are integrated into a halter and positioned under the jaw or fixed at the side of the lower jaw. Measurement devices belonging to acoustic biotelemetry use acoustic signals to monitor jaw movements in cattle (Alkon and Cohen, 1986). However, only the regurgitation process during rumination can be measured while other jaw movements are not ascertainable (Lindgren, 2009; Bar and Solomon, 2010).

However, although the most considerable progress in monitoring and understanding grazing and foraging behavior, in sheep, goats and cattle, was made by Penning (e.g. see Penning and Rutter (2004), Parsons et al. (2013)), some of the systems mentioned above show ample room for further improvement, which accords with statements of Kononoff et al. (2002) and Schirmann et al. (2009). The existing inadequacies of some of these systems have led to the development of other systems in order to overcome most of described and still remaining difficulties. A key requirement for further progress was the advancement of electromyography usage (De Luca, 1997; Hermens et al., 2000).

The overall objective of this study was to evaluate a new electromyography-based (EMG) system for monitoring feeding behavior in dairy cows. The objectives were (1) to determine the precision of EMG compared to direct visual observation and (2) to establish how accurately RT and FT are depicted by comparing this new system to visual observation.

2. Material and methods

2.1. Measurement system

The system, labeled as DairyCheck is a non-invasive, sensor-based system for monitoring feeding behavior which works without further auxiliary means. It consists of a measurement halter with two incorporated electrodes, a data logger and a power supply, as shown in Fig. 1. A three-dimensional accelerometer to determine movement activity of the whole body and evaluation software are also incorporated. To warrant an accurate and optimal positioning of the electrodes within the halter, the size and scatter ranges of the heads of more than 300 cows have been measured. These values have been utilized for creating a best fitted halter. Consequently, the halters are individually adaptable for optimal attachment of the electrodes to the *Musculus masseter*, which is important for the accurate measurement of valid data. To comply with good functionality, the halter is soft padded and comfortable and does not affect the cow's well-being. The whole system has been manufactured by BITSz engineering GmbH, Zwickau, Germany. Measurement of feeding behavior ensues through electromyography with modified electrodes, which are closely attached to the skin of the cow. When positioning the electrodes and measuring electrical impulses, the *M. masseter* was chosen because of its size and importance as well as its previous use in electromyographic studies (Griffin and Munro, 1971; Lewis et al., 2013). Besides the *Musculus temporalis*, the finely feathered muscle

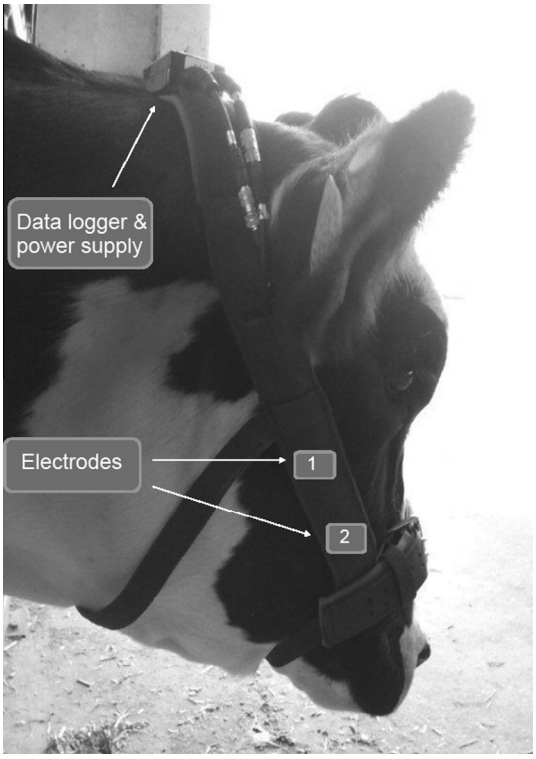

Fig. 1. DairyCheck halter with data-logger, power supply and incorporated electrodes as fitted to cattle.

M. masseter is the most powerful chewing muscle in terms of size and power performance and has a large cross section area. It is involved in the closure of mouth, in forward movements and sideways-looking movements, which are typical grinding movements of herbivores (Surwald, 2001) and is therefore an essential component of the motion system of the mandible. By means of two surface electrodes the electrical potential oscillations of the external masticatory muscle of the *M. masseter* during jaw movements are recorded with a resolution of 600 measuring points per minute. The myo-electrodes are connected to a data logger, which is integrated into a protective box. This box is placed on the top of the halter and is used for storing the power supply. The data logger registers the electrical impulses and saves them to a mobile central data processing unit for up to 11 h, after which the first recorded minute is overwritten. If the connection between the data logger and the computer is disconnected, data can be saved for up to 11 h.

Direct raw data transmission (BITSz engineering GmbH, Zwickau, Germany) takes place via bi-directional radio transmission at a frequency of 2.4 GHz. Thereby, live observation and constant monitoring of feeding behavior in real time is possible. The system is powered by a rechargeable 3.7 V, 2.7 Ah lithium-ion battery which allows up to three weeks of uninterrupted recordings.

2.2. Working principle

The system enables the automatic and continuous measurement of individual jaw movements. Generated data are automatically evaluated in terms of graphs, where a plot of the amplitude of the signal from the electrodes against time is displayed. The software, which is based on an algorithm with animal specific values, then identifies single jaw movements, and uses the frequency, amplitude and shape of the jaw movement waveform to discriminate between active feeding and rumination phases and non-active dormant phases. Thus, the algorithm for analysis is based on