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Validation of a pressure sensor-based system for measuring eating, rumination and drinking behaviour of dairy cattle

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ABSTRACT

The main objective of our study was to validate, for dairy cows, a new pressure-based system (RumiWatch noseband sensor, Itin + Hoch GmbH, Liestal, Switzerland; RWS) that measures eating, rumination and drinking time. In experiment 1, eating, rumination and drinking time (RWS, min/h) measurements were compared with continuous behaviour recording (CR) of six dairy cows in tie-stalls (a total of 72 h). In addition, eating time measured by RWS was compared with the visiting time at automated feeders of a widely used type (Roughage Intake Control, RIC, Insentec BV, Marknesse, The Netherlands) to gain experience of the utility of RWS in a loose-housing system (experiment 2). A total of 403 h of RWS and RIC data from 18 cows was used for these two comparisons in experiment 2. In experiment 1, RWS and CR had a very dependable relationship (random coefficient regression model) for eating and rumination: eating, $y = 0.98\ (0.89–1.07)x + 3.25\ (1.35)$ (the slope with the 95% confidence interval and the intercept with standard error of the mean) and rumination, $y = 0.88\ (0.73–1.02)x + 1.77\ (1.00)$. The R^2 values were 0.94 and 0.93, respectively, i.e. random error was small. The 95% confidence intervals of the slopes included value 1, and the intercepts did not differ from 0; i.e. there was no significant systematic error. However, experiment 2 confirmed a tendency observed in experiment 1 that RWS overestimated eating, since RWS eating time (5.1 ± 2.7 h/24 h) exceeded significantly visiting time (RIC) (3.2 ± 1.1 h/24 h; paired *t*-test, $n = 18$) in the setup where, in principle, eating was possible only in the RIC feeders. In experiment 1, the relationship between drinking time (RWS) and CR was poor: $R^2 = 0.20$, and $y = 0.49\ (0.12–0.85)x + 0.64\ (0.13)$. However, this may reflect more the challenges in measuring drinking in general than merely with RWS. In conclusion (i) the RWS results were relatively free from random errors for rumination and eating, but not for drinking, (ii) there was systematic error for eating and drinking, but not for rumination, and (iii) due to the relatively limited size of our data, further validation of RWS is recommended and RWS needs further development at least for eating and drinking measurements.

1. Introduction

Eating, rumination and drinking are essential components of the nutritional behaviour of dairy cows (Phillips, 2002). In scientific studies, the feeding behaviour of loose-housed cattle has been measured traditionally by direct observation methods. Automated equipment for measuring feeding behaviour and feed intake of cattle is, however, used more and more widely, because of the very labour-intensive requirements for conducting visual observations of behaviour (Beauchemin et al., 1989; Elischer et al., 2013). These types of automated equipment could also be of great benefit in large commercial dairy herds because ingestive behaviour can also be regarded as an important parameter for predicting health issues (as reviewed by Weary et al., 2009).

Devices used for measuring the feeding behaviour of dairy cows can be classified into two categories: stationary systems and systems based on sensors attached to animals. Stationary feeding systems use transponder tags that identify the individual animals and measure either the duration of visits at a feed alley (DeVries et al., 2003) or the visit duration and feed intake at feed troughs

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(Chapinal et al., 2007; Chizzotti et al., 2015). The feed intake measurements are based on the weight difference of the feed before and after a visit.

Sensor-based systems utilise various technological solutions for measuring the movements of the head and jaws of the animals, or the feeding behaviour sounds (reviewed by Delagarde and Lamberton, 2015). Some devices measure only rumination (a microphone: Schirmann et al., 2009; Ambriz-Vilchis et al., 2015) and others only grazing (an accelerometer: Ueda et al., 2011; Nielsen, 2013; Delagarde and Lamberton, 2015), but there are also devices that measure both of these behaviours (micro and mercury switches: Stobbs and Cowper, 1972; an electrical resistance sensor: Rutter et al., 1997) or rumination and eating (a pressure sensor: Braun et al., 2013). Recently, the RumiWatch pressure-based noseband sensor (RWS) (Itin + Hoch GmbH, Liestal, Switzerland) has been developed for measuring eating, rumination and drinking time in dairy cows (Zehner et al., 2012). The measurements of the system are based on an oil-filled silicone tube containing a pressure sensor fastened in a halter over the cow's nose. Although stationary systems are accurate in their measurements of feeding behaviour and feed intake, one of their disadvantages is high investment costs. The sensors that are attached directly to the animal are usually low-cost and they also enable feeding behaviour measurements in different rearing conditions (e.g. in the pasture).

The main objective of the current study was the technical validation of eating, rumination and drinking times as measured by RWS, compared with continuous behaviour recording (CR) (experiment 1). In addition, eating time (RWS) was compared to visit time of roughage intake control (RIC) feeders (experiment 2) to gain wider practical experience of RWS; i.e., not only in tie-stalls (experiment 1) but also in a loose-housing system (experiment 2).

Fig. 1. A cow equipped with a RumiWatch noseband sensor. The pressure sensor is placed in the noseband of the halter (pointed by an arrow).

2. Materials and methods

The experiments were carried out at MTT Agrifood Research, Maaninka Finland (from 2015 this became Natural Resources Institute Finland) during April–May 2013. All management and experiment procedures complied with Finnish animal welfare legislation.

2.1. Experiment 1

In experiment 1 one primiparous and five multiparous (parity = 2.5 ± 0.84; mean ± standard deviation for the six cows) non-lactating dairy cows (three Nordic Red, three Holstein) were housed in tie-stalls with peat bedding. The cows were fed grass silage (dry matter 22–26%) delivered two times each day during the experiment. Water was provided ad libitum from water bowls (diameter 25 cm).

Each of the six experimental cows was equipped with a RWS at the beginning of the 48-h trial period (Fig. 1). Cows were habituated to the RWS for a few hours before the experiment started. Video cameras recorded the behaviour of the cows continuously, 24 h for each animal. The video cameras used in the experiment were from Axis, models Q1755-E (four cameras), 215 (one camera) and 211A (one camera). The animals were always visible in at least two cameras, one shooting the front of the animal and one the view from behind the animal. The rear camera was placed approximately 0.5 m behind the animal and 4 m above ground, the front cameras approx. 1 m in front of the animal and 3 m above ground. The cameras were directed towards the animals' heads. As the three cows were placed next to each other in a tie stall at the same time, and as the view of the cameras overlapped somewhat, it was often possible to check the behaviour of the observed animal from at least two more angles from the cameras of the neighbouring animals – and in unclear cases this was done. During the experiment some lights in the barn's tie-stall section were turned on also during the night (not full lighting in order not to disturb the animals) to facilitate seeing. The time settings of the video and RWS systems were synchronised before the experiment.

Two trained observers monitored video recordings showing the eating, ruminating and drinking time (resolution 1 s) of the cows with the CR method (Martin and Bateson, 2007), a total of 12 h per cow. Eating was registered when a cow took feed into its mouth, chewed and swallowed it. Cow behaviour was registered as ruminating when the cow regurgitated a bolus, chewed and re-swallowed it. Drinking was registered when the cow put its muzzle into the water bowl and swallowed water. The between-observer reliability (Martin and Bateson, 2007) was tested by comparing four one-hour continuous recording observation periods from both observers. The measurements of eating, ruminating and drinking time recorded by the two observers were highly correlated. The coefficients of determination (R^2) for the regression equations exceeded 0.99 for all behaviour categories, and the slopes and intercepts were 1.08 and 14 s, 1.01 and 4 s, 1.77 and −1 s, respectively.

2.2. Experiment 2

The cows in experiment 2 were two primiparous and 16 multiparous (parity = 2.6 ± 1.2; four Nordic Red and 12 Holstein) lactating cows (days in milk = 103 ± 108 d; milk production = 34.0 ± 10.5 kg/d; mean ± standard deviation) kept under loose-housing conditions. The cows were fed two different kinds of total mixed rations consisting of tall fescue mixed with red clover, barley, rapeseed and minerals. The grain:forage ratio (dry matter basis) for total mixed ration 1 (dry matter 26%) was 18:82 and for total mixed ration 2 (dry matter 34%) 48:52. Three cows were fed total mixed ration 1 (from three feed troughs) and 15 cows were fed total mixed ration 2 (nine troughs). The total mixed rations were delivered from a forage shuttle six times a day. The experimental compartment had 24 free-stalls with peat bedding and 12 Roughage Intake Control (RIC) troughs (Insentec BV, Marknesse, The Netherlands). The RIC troughs controlled access to the total