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Application of a noseband pressure sensor for automatic measurement of horses' chewing activity: a pilot study

Jessica Werner, Nils Zehner, Christina Umstatter, Franz Nydegger and Matthias Schick,

Agroscope, Institute for Sustainability Sciences, 8356 Ettenhausen, Switzerland

Christa Wyss, Agroscope, Swiss National Stud Farm, 1580 Avenches, Switzerland

Matthias Hoch, Itin+Hoch GmbH, Feeding Technology, 4410 Liestal, Switzerland

Abstract

Chewing activity of horses is an important parameter for health and welfare monitoring. The aim of this study is to determine the feasibility of a sensor-based automatic measurement system for registration of this behavioral parameter. An existing sensor-based animal monitoring system (RumiWatchSystem, Itin+Hoch GmbH, Liestal, Switzerland) consists of a noseband sensor, pedometer and evaluation software. It is well equipped for recording of ruminating, eating, drinking and motion behavior in dairy cows. In this study it will be used on horses for identifying the specific differences between horses and cattle in chewing activity with the purpose to adapt the system to horses.

Under the same conditions (single boxes, straw bedding, fed 2 times daily) 10 horses (5 mares, 5 stallions) were observed visually to evaluate the accuracy of automatic measurement. The results of direct observation were compared to the automatic evaluation of eating times and number of eating chews generated by the noseband sensor. Direct visual observation was carried out on roughage and concentrate intake. During the study, horses were used for riding, driving and for other activities as usual.

Preliminary data analysis revealed that the sensor system is able to generate consistent measurement results of horses' chewing activity. For further development, the technical components and analysis algorithms need to be adapted for explicit application in equids.
After additional steps of development and research, future application potentials of the system are health monitoring, nutrition management and behavioral research in horses to improve husbandry systems and animal welfare.

Keywords: horses, chewing activity, automatic measurement

1 Introduction

In modern husbandry of domestic horses, feeding conditions contribute highly to individual animal health and welfare. Evolutionary, horses are grazing animals adapted to the poor vegetation of steps. This leads to a continuous intake of low energy and high fiber feed during long feeding bouts. Physiological, horses are well adjusted to these feeding conditions due to the structure of the gastro-intestinal tract, e.g. with a large caecum using microbiological fermentation. In comparison to feral horses which spend 12-16 hours with feed intake behavior (ZEITLER-FEICHT 2008) and travel up to 28 km a day (HAMPSON et al. 2010), domestic horses are mainly stabled with individually rationed forage intake and an additional feed of grain. These deficits of shortened feed intake time and missing activity in their feeding behavior may lead to physiological and ethological problems in animal health and welfare. Horses may compensate the lack of feeding time with abnormal behavior or stereotypies.

Chewing activity, particularly jaw movements, is a measureable and empiric parameter in the monitoring process of feed intake behavior. Different scientists worked on the development of an automatic measurement system of horses' chewing activity (BÜSSOW 2006; BONIN et al. 2007). One option is the electromyographic evaluation of masseter muscle activity used in a study of VERVUERT et al. (2012) but most of these solutions are either invasive or not practicable. The RumiWatch system (developed by Agroscope and Itin+Hoch) is a well-established automatic measurement system for cows to record chewing and movement activity (ZEHNER et al. 2012). The system is reliable and can be used to measure the number of chews while an animal is ruminating or eating. In addition, the amount of time spent drinking can also be recorded.

A pilot study was conducted in collaboration with the Universität Hohenheim, Agroscope Tänikon, the Swiss National Stud Farm and the industry partner Itin+Hoch GmbH. The aim of this study was to investigate the feasibility of adapting the RumiWatch system to horses. The objective of this research was the development of an novel and reliably working monitoring tool for quantitative recording of horses' chewing activity. Former studies can be found in literature about eating behavior but they were mostly based on qualitative observations (BOYD et al. 1988). With the possibility of this technology, new findings concerning horse behaviour and welfare may be made. Such results could be used to analyse and optimise feeding and housing conditions of domesticated horses in modern husbandry systems.

2 Materials and methods

2.1 Automatic measurement system

The RumiWatch system (Itin+Hoch GmbH, Liestal, Switzerland) consists of a noseband sensor, a data logger with on-board data analysis and software package (RumiWatch Converter V0.7.2.0 and RumiWatch Manager Version 0.9.6). As described in NYDEGGER et al. (2011), the sensor system is integrated in a conventional halter (Figure 1). An oil-filled silicon tube with a pressure sensor is integrated into the noseband. It transmits the signals to the data logger which is incorporated into a plastic box at the end of the nosepiece on the right hand side. The signals of chewing activity are picked up through the change of pressure in the silicon tube, implicated in the noseband, with every jaw movement. Logging rate of the sensor is 10 Hz and raw data are saved to a SD memory card located in the plastic box on the right hand side.

Figure 1: Components of the RumiWatch system and example of practical use.

The second box (on the left) is used as a protective cover for the power supply, a 3.6 V battery, lasting up to 3 years under laboratory conditions due to a low energy operating system. Raw data can be downloaded via a USB plug-in connection or remote via the software package. Using generic algorithms, raw data can be classified as rumination, eating and drinking as well as other activity. In its current state, this monitoring system is developed for cows. All these parts enable a simple use of the halter under experimental or practical conditions. This system could also be very useful for horses. It might even be able to classify the intake of different feed types due to algorithms detecting varying rhythmicity in different feeds. Therefore, the aim of the study was to evaluate the application and accuracy of the noseband sensor to investigate chewing activity in horses.

2.2 Experimental design

Ten horses (5 stallions, 5 mares; 8 Freiberger, 2 Swiss Warmblood; aged 8 to 17 years; body mass 601 ± 38 kg), stabled individually on straw bedding, were used. They were fed with hay and concentrate twice daily. During their feeding bouts, periods of 10 min were observed visually while counting chews using an Microsoft Excel sheet (on a tablet computer). Only chews and bites, which led to hay intake were counted and in the following referred to as 'chews'. The observer relied mainly on the sound of grinding teeth for her data collection. In this paper we focused on hay intake only.

Table 1: Experimental design for direct observations during hay intake. The noseband sensors were attached and recorded continuously.

Number of horses	Observational period (min)	Number of observations per horse in total
10	10	3 (AM) 3 (PM)

Due to difficulties with the devices and illness of one animal, there were only 4 periods for Horse 1 and 5 periods for Horses 2 and 9 observed.

2.3 Validation and statistical analysis

A comparison between visual observations and the automated measurement system was done to evaluate the feasibility of applying the RumiWatch system to horses. Therefore, the observed data were collected with Microsoft Excel 2010 and analysed with the statistical package SPSS (Version 22, IBM, Armonk, NY, USA).
Firstly, the means of the number of chews per 10-minute period of all horses measured visually and automatically were compared. They were normally distributed (p=0.200), hence, we used a parametric statistical test.
Secondly, the agreement between visual and automated measurement was analysed by using the following formular:

Agreement in percentage = $\frac{Chews(aut)}{Chews(vis)} * 100$

Chews aut = amount of chews measured automatically in a 10-minute observation period
Chews vis = amount of chews measured visually in a 10-minute observation period

In Table 3 the means and standard deviations of all observational periods per horse were compared. The means of agreement are normally distributed (p=0.200) Therefore, we made use of a parametric statistical test.

Finally, the linear relationship between visual and automated measurement of horses' chewing activity was analysed with the Pearson product-moment correlation coefficient.

3 Results and discussion

Figures 1 and 2 show the chewing activity of horses. Every single peak indicates a jaw movement. In Figure 1, Horse 1 was chewing hay and the data logger classified the jaw movements as eating. In Figure 2 the data logger classified the chewing activity differently. As the sensor is developed for ruminants, it classified these jaw movements as rumination. This is the case when the algorithm used detects a higher degree of rhythmicity. In horses this algorithm could be adapted and used to identify a steady and continuous chewing activity. It could also be valuable to classify different feed types. These results will be presented in subsequent studies.

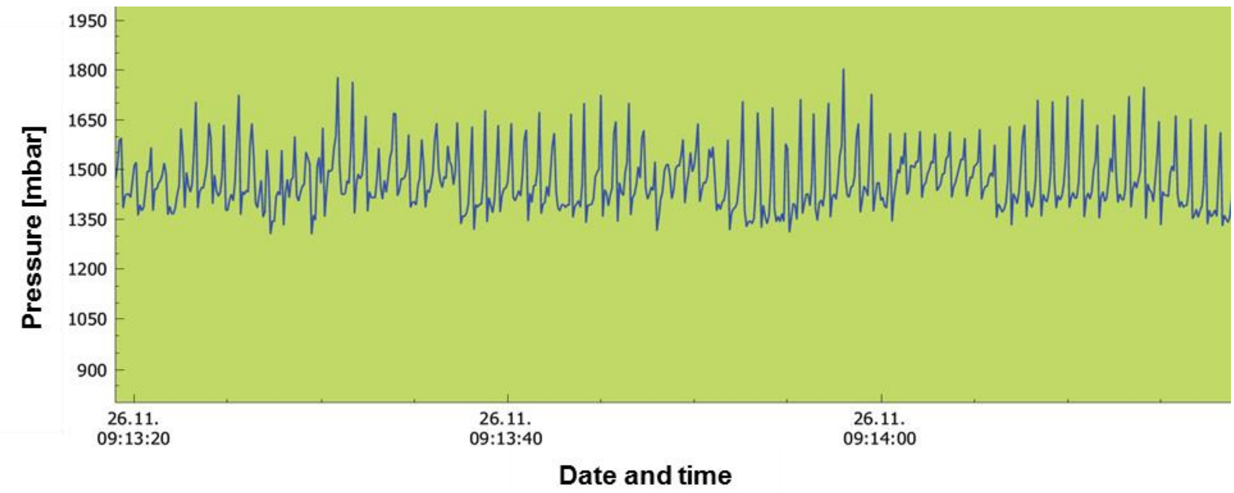

Figure 1: Pressure signals of horses' chewing activity of hay recorded with the RumiWatch noseband sensor.

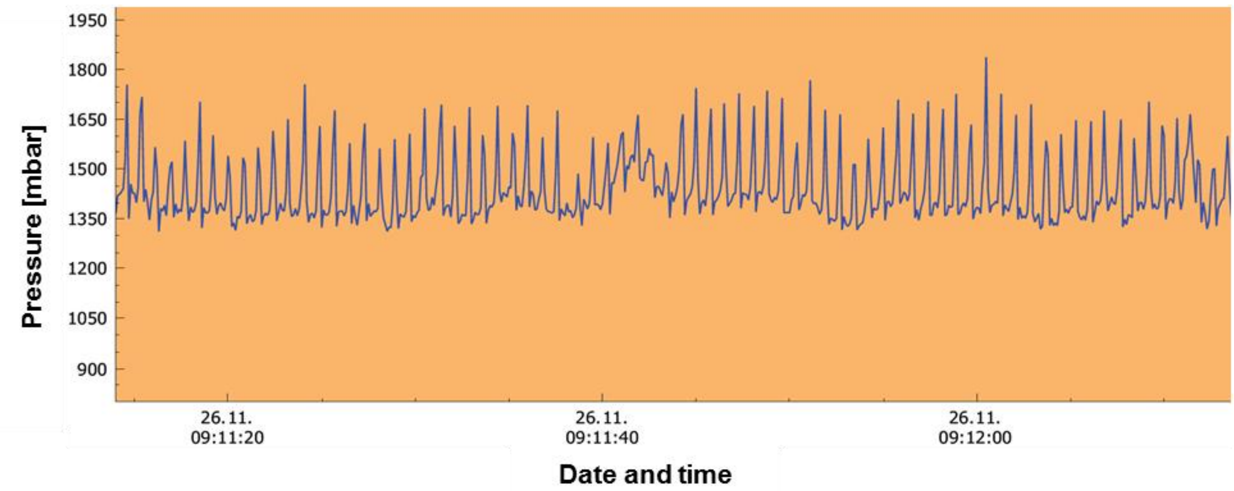

Figure 2: Pressure signals of horses' chewing activity of hay recorded with the RumiWatch noseband sensor. This examples shows higher rhythmicity and was detected by the 'rumination algorithm'.

First results of number of chews, counted during observational 10-minute periods while the horses were eating hay will now be presented. The average number of chews counted through visual observation was 705 ± 90 in comparison to the automated measurement system with 757 ± 82 chews. Both mean values agree with several sources in literature of 60-80 chews/min (FRAPE 2008; ZEITLER-FEICHT 2008; MEYER et al. 2014). However, the range of number of chews between all observational periods varies from 436 to 896 chews counted visually and from 430 to 905 chews measured automatically. This span might be caused by the fact that some horses tend to be distracted and screen the environment frequently while feeding. SWEETING et al. (1985) discovered such an effect of social facilitation of feeding. Due to an individually housing of the horses in our trial, they may tended to stop eating to make contact with neighbouring horses.

For statistical analysis, the results were tested for normal distribution and followed a bell curve (p=0.200). Due to this finding, the significance of difference in means between visual observation and automatic measurement system was statistically tested with a parametric statistical hypothesis test. The fact of matched pairs led to the paired t-test. It confirmed that the difference in means were highly significant (p=0.001).

The mean deviation for the individual horses between both recording methods ranged from -11 chews per 10 minutes observation (Horse 2) to 96 chews per 10 minutes observation (Horses 5 and 9). Thus, positive amounts of chews represent a higher value of the automatic measurement system. The single negative amount in Horse 2 with -11 chews in comparison to the visual observation demonstrates a lower value of automatic recording.

Table 2: Mean and standard deviation of chews counted per horse comparing visual (vis) and automated (aut) measuring periods (10 min. intervals).

Horse	**Gender**	**N**	**Mean ± SD of chews vis**	**Mean ± SD of chews aut**
1	Female	4	684 ± 32	771 ± 61
2	Female	5	644 ± 62	633 ± 40
3	Female	6	699 ± 25	777 ± 14
4	Female	6	621 ± 92	650 ± 110
5	Female	6	645 ± 39	741 ± 17
6	Male	6	803 ± 73	842 ± 50
7	Male	6	782 ± 27	805 ± 19
8	Male	6	782 ± 40	824 ± 30
9	Male	5	623 ± 129	719 ± 68
10	Male	6	738 ± 56	790 ± 40
total		56	705 ± 90	757 ± 82

N = Number of recorded hay intake periods (one period had a 10 minute duration)
SD = standard deviation

The visual observations was set as the gold standard for this study, because it is feasible to differentiate between eating chews versus other jaw movements. This reference method was already established for the evaluation of automatic measurement systems in other studies (BURFEIND et. al. 2011; NYDEGGER et. al. 2011; ZEHNER et. al. 2012).

Therefore, the accuracy of the automated measurements was defined by the agreement of counted chews between the two methods, visual observations and automated recordings with the RumiWatch system.

Table 3 presents the results of each horse concerning the mean of agreement between the two observation methods. It is remarkable that in general the mean of agreement has a value above 100%. The highest value with 117.7 % can be found in Horse 9. This shows the greater sensitivity of the automated measurement system and results in a higher value of counted chews. The number of chews of Horse 2 (98.7 %) is the only exception. In conclusion, there were jaw movements recorded automatically as chews, which were not counted as chews by visual observation. These detected movements of mandibular motion could be licking, biting or some other activities. This needs to be investigated further in a follow-up study.

The range of deviation in percentage (automatic versus visual) from 100 % varies from -1.3 to 17.7 % between the ten horses, whereas total deviation accounts for 8 % between all horses and measurements. This result is acceptable for a system, which is not adapted to horses. It is also interesting that a software developed for cattle has such a high success rate when used on a different species. The statistical analysis with a t-test reveals a highly significant difference within the mean of agreement. (p=0.000)

Table 3: Mean and standard deviation (SD) of agreement between the two observational methods, visual observation (vis) and automated measurement system (aut).

Horse	**Gender**	**N**	**Mean of agreement (aut /vis) [%]**	**SD of agreement (aut/vis) [%]**
1	Female	4	113.2	13.9
2	Female	5	98.7	6.7
3	Female	6	111.3	4.4
4	Female	6	104.4	4.1
5	Female	6	115.2	8.4
6	Male	6	105.1	3.5
7	Male	6	103.1	2.5
8	Male	6	105.4	3.0
9	Male	5	117.7	15.5
10	Male	6	107.3	4.8
total		56	108.0	8.7

N= Number of recorded hay intake periods (one period had a 10 minute duration)
SD= Standard deviation
agreement [%] = (Chews(aut)/Chews(vis))*100

The linear correlation between the number of chews measured visually or automatically was calculated (Pearson) and is shown in Figure 2. The correlation was highly correlated (r=0.83; p=0.000). The linear relationship demonstrates a high agreement of the automated measurement system with the visual observations.

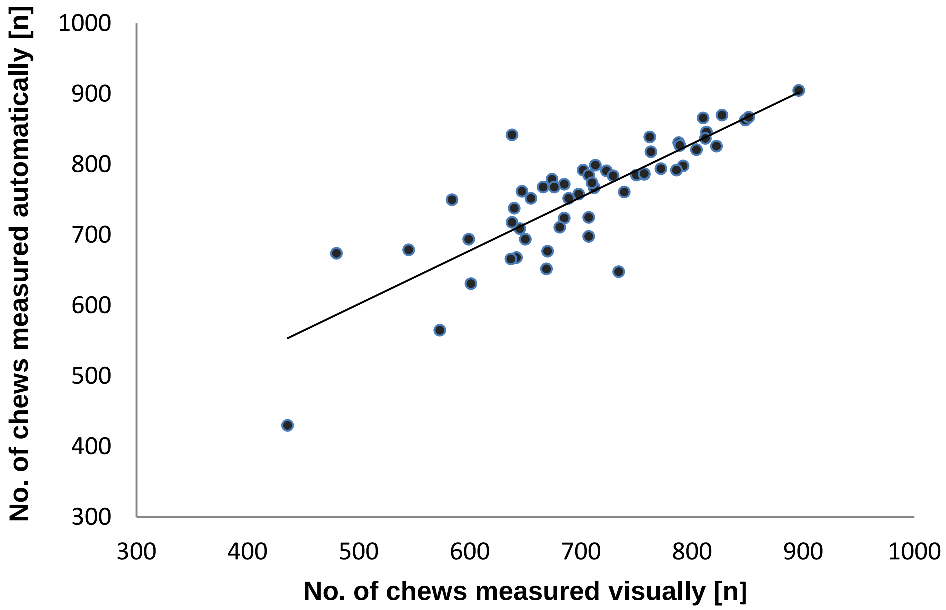

Figure 3: Correlation between number of chews measured with both methods (automated and visual; N= 56; R^2= 0.69; r= 0.83).

4 Conclusions

Results of this study have shown successfully that it is feasible to use the automated measurement system “RumiWatch” for horses. The mean deviation in percentage between visual and automatic observations is approximately 8% in total. This is highly encouraging regarding the fact that the system was developed and calibrated for cows. Nevertheless, the system needs to be refined in further research projects in order to be used as a reliable monitoring tool. Once it is optimised, it can provide useful information regarding behavioral, nutritional and health concerns.

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