ASSESSMENT OF DAILY FEEDING BEHAVIOUR OF HORSES WITH AUTOMATED CHEW MONITORING DEVICE

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Abstract: *Behaviour is one of the most important indicators for assessing horse health and well-being. However, direct observation traditionally relies on observation methods that are time consuming and can limit the accuracy and the amount of data collected. Therefore, several systems have been developed to automatically record behavioural traits, including the RumiWatchSystem (Itin and Hoch GmbH, Liestal, Switzerland). The aim of our experiment was to evaluate the usefulness of the presented technology in studies of equine feeding behaviour and to compare the differences in chewing activity when different forms of feed are added. The trial lasted nine days and was carried out on three mares. The mares were fed hay, and on the fifth day the concentrate was introduced. The results showed that the mares spent 9.08 hours feeding, with low intake activity in the early morning hours (00:00 - 8:00) and around midday and significant peaks in intake in the morning and late afternoon. The study confirmed that the developed monitoring sensor system was successful in monitoring the feeding behavior of horses.*

Key words: *noseband sensor, mares, feeding time, chewing activitiy*

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1. Introduction

Precision livestock farming can be defined as non-intrusive, real-time monitoring technologies that aim to control the temporal variability of the smallest manageable unit of production, which is known as the "per animal approach" (Halachmi & Guarino, 2016). This technology aims to improve animal welfare and farm management. Remote monitoring, advanced data collection through sensors, fast data transmission and extensive data storage have advanced precision livestock farming in many areas of animal production. Sensor technology has become available in many forms, monitoring location, activity and behaviors in grazing and foraging, early detection of lameness and other diseases, milk yield and composition, reproductive measurements and calving diseases, as well as feed intake and greenhouse gas emissions (Tedeschi et al., 2021). The gradual introduction of these technologies brings various benefits, such as increasing the quantity and quality of products, reducing human labor and lowering resource consumption. Continuous monitoring of behavioral and physiological indicators can make it possible to detect subtle changes before they manifest as overt clinical symptoms (Boyd, 1998). In addition, digital technologies are crucial to addressing important adaptations in livestock production such as climate change and animal welfare (Janzekovic & Prisenk, 2017; Gonçalves et al., 2022). Precision livestock farming rapidly evolves and moves beyond health alarms towards an integrated decision-making system (Kleen & Guatteo, 2023). It is, therefore to be expected that the importance of these technologies will steadily increase in the coming decades.

Various sensors and information technologies have been developed to monitor the precision feeding of herbivores. Nutrient supply and demand, or input and output, are the main targets to be managed (Prisenk et al., 2013). The nutritional processes start outside the animal's body with the available feed (quantity and quality) and continue inside the body when the feed is consumed, degraded in the gastrointestinal tract and metabolised by organs and tissues. Finally, some nutrients are wasted through urination, defecation and gas emissions through breathing and burping, while the remaining nutrients ensure maintenance and production. These nutritional processes could be managed and optimised with timely and accurate information provided by sensor technologies (González, et al., 2018).

Feeding behaviour is an important parameter for the performance, health and welfare of animals and also reflects the quantity and quality of available feed. Adult equids spend more time eating than any other category of behaviour (Berger et al., 1999; Prisenk et al., 2013). Foals begin feeding on adult food sources, especially grasses, on the first day of life and develop a time budget for feeding as they get older. In the wild, horses spend approximately 60 % of their daily behaviour foraging (12–16 hours per day), and voluntary feeding breaks rarely last longer than 4 hours per bout (Ellis, 2010). For many stabled horses, particularly those not fed *ad libitum* feed, the time spent eating and foraging is considerably lower than this. This lack of foraging opportunities leads to a reduction in chewing time, which in turn can have a negative effect on the digestive system and encourage the development of stereotypies.

However, the apparent increase in overweight horses and the associated health risks have led to the need to reduce calorie intake in many animals (Harris et al., 2010). This usually leads to a further reduction in foraging opportunities and a general recommendation to use strategies that increase the eating time of the forage fed (Ellis et al. 2015).

Studies of equine grazing that include behavioral assessments have traditionally relied on observational methods to evaluate grazing activity. These observational protocols limit both the accuracy and the amount of data collected. Observational studies are inherently time and labor intensive. Therefore, there are few such studies that provide a complete and continuous 24-hour data set. Continuous automated monitoring systems represent an alternative strategy for quantifying equine behavior on pasture, but this approach has only been used to a limited extent in equine grazing studies (Weinert et al. 2020).

Although not widely adopted in equine grazing research, there is a comparatively extensive history of automated monitoring approaches in cattle grazing studies. One such commercially available technology, the RumiWatchSystem (RWS; Itin and Hoch, GmbH, Liestal, Switzerland), functions as a chewing sensor. Originally developed by Nydegger and Bollhalder (2010), the RWS has been validated for recording parameters of feeding behavior in cattle managed in both indoor housing (Zehner et al., 2017) and on pasture (Rombach et al., 2018). An equine version of the RumiWatch System, the EquiWatchSystem (EWS; Itin þ Hoch; GmbH), has been validated for recording jaw movements in stabled and pasture horses eating small meals of concentrate, silage or hay. The percentage agreement between the EWS and complementary visual observations was 93 % for all feeds tested and 95 % when feeds alone were assessed (Werner et al., 2016; Weinert et al. 2020).

Based on the previous considerations, the objectives of the present study were to (i) evaluate the usefulness of the newly developed EWS in studies of equine feeding behaviour, (ii) analyze the feeding behaviour of mares and to present the daily feeding routine, and (iii) compare the differences in chewing activity when different forms of feed are added.

2. Materials and methods

The investigation took place at the Korosec family farm. The farm is located in the municipality of Poljčane, more precisely in the town of Spodnja Brežnica. The study was performed following the Slovenian Law on Animal Protection, and approved feed additives were used (European Union Register of Feed Additives, 2013).

2.1 Sensor technology

In our study we used EquiWatchSystem (EWS). The physical and software components of the EWS are the same as those of the RWS, which is primarily intended for the study of feeding behavior and rumination in cattle. The RWS consists of a noseband sensor and two separate associated computer programs for sensor management and control (RumiWatch Manager) and data analysis (RumiWatch Converter).

The EWS version uses the same nasal sensors and the same computer program (RumiWatch Manager) to manage the sensors as RWS. The only difference is the RumiWatch Converter, a computer program for data processing.

The system components and their functions have been described in detail in previous publications (Werner et al., 2016; Zehner et al., 2017; Weinert et al., 2020). The presented EWS noseband sensor was developed by Agroscope Institute for Sustainability Sciences (Ettenhausen, Switzerland) in collaboration with Itin+Hoch GmbH and InnoClever GmbH (both Liestal, Switzerland) and enables automated measurements of ruminating, eating, and drinking behavior.

The noseband sensor allows to detect the jaw movements of the animal and comprises following components (Figure 1):

– liquid filled pressure tube,
– pressure sensor (at the end of the tube),
– box (left) containing the battery set,
– box (right) with a USB interface containing the data logger, an acceleration sensor, a temperature sensor and a micro SD-card holder,
– connection cable between both the boxes,
– and nasal sensors.

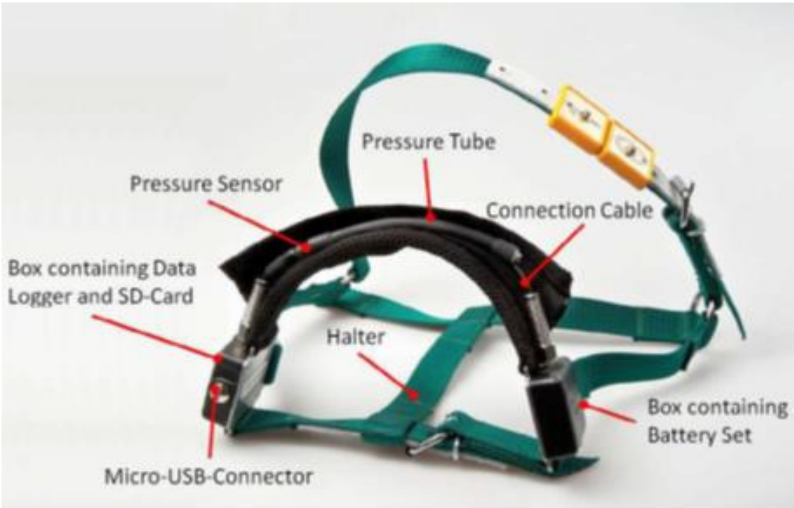

Fig. 1. EquiWatch noseband sensor components (User Guide RumiWatch).

The EWS noseband sensor consists of a glycol-filled silicone pressure tube for sensing the jaw movements of the animal, a three-axis accelerometer to detect three-dimensional head movements, and a temperature sensor, for measuring the temperature within the box containing the data logger (Zehnter et al., 2017). The evaluation of the collected data occurs in real time within the data logger of the noseband sensor. The raw data being logged with a rate of 10 Hz (e.g. every 1/10 of second) may be saved on a micro SD-card before being transmitted to a PC through the micro USB interface. Independently, hourly summaries of the animal behaviour can be wirelessly transmitted to a PC. A battery set supplies the needed power for the data logger and for the writing (saving) of the raw data onto the SD-card.

A protective box that holds the data logger is located on the nasal sensor's right side, while on the left side, a similar protective box contains a two 3.6 V battery power supply. Battery life spanned approximately100 days of raw data logging.

The EWS is associated with software packages for managing the sensor (RW Manager) and analyzing raw data (RW Converter). The RumiWatch Manager is a software tool allowing to plan and to execute all measured activities with the RumiWatch System. In addition it can also be used to visualise the collected data. In our study we used RumiWatch Manager 2 (version 2.0.0).

RumiWatch Converter is a software for user-defined analysis, processing and graphical representation of data measured by RumiWatch Noseband Sensor. The algorithms of the RumiWatch Converter identify patterns in the raw output from the pressure sensor and accelerometer. Specific behaviors (eating, drinking, other activity, etc.) are assigned based on the recognized pattern signatures. In our study we used RumiWatch Converter (version 0.7.4.15). This version includes a "Horse Mode" option for transforming the raw data collected from the EWS into summaries (Microsoft Excel format) of feeding behavior parameters at intervals specified by the user. The algorithms are adapted to recognize the eating, drinking chewing and swallowing of horses, which differs from cattle that spend a considerable amount of time ruminating in addition to the above-mentioned processes.

2.2 *Animals, housing, feeding management*

In the experiment, we monitored the daily feeding behavior and chewing activity of each mere individually, how many bites and chews it makes in a certain time and thus the correspondence with the recorded daily rhythm of the animal. The experiment lasted 9 days, from 5. April 2024 to 14 April 2024.

Three healthy mares were used for our studies. Horses received regular veterinary and dental health care, with the most recent dental examinations conducted within 6 months before the start of the study.

A log of daily feeding and other activities was kept for the entire duration of the trial. The horses were always fed at the same time, namely in the morning at 8:00 am and in the evening at 6:00 pm. The small square bales of hay were weighed before feeding to determine the feed offered and then placed in the four separate feeding nets attached to one and a half meter high poles (Fig. 2). Before each subsequent feeding, the remaining feed was weighed if it remained in the net.

Fig. 2. Method of feeding the mares in the trial (Ferlez, 2024).

The study was divided into two test periods. In order to evaluate the differences in chewing activity between the different feed types, we used different types in the first and second part of the trial. In the first part of the trial (the first five days), the mares were fed only hay (morning and afternoon). In the second part (the last four days), the mares received hay in the morning and concentrated feed in the afternoon.

Feeding management was adapted to the experimental design. All horses were fed twice daily. The sensory analysis of the feed revealed good quality. As the mares were not physically active on the first day, they only received a daily supply of hay corresponding to their body weight. On the third, fourth and fifth day of the trial, light physical activity was carried out, so that the amount of feed was increased for maintenance (according to body mass) and for light work (Tab. 1).

Mare	**Time of feeding (hr)**	**Type of forage**	**Amount of feed (kg)**	**Feed residue (g)**
Boni	8.00	Hey	3.6	0
	18.00	Hey	3.6	0
Astrid	8.00	Hey	5.1	0
	18.00	Hey	5.0	0
Afrodita	8.00	Hey	6.2	0
	18.00	Hey	6.3	0

Tab. 1. Feeding management of mares in second trial period.

On the fifth day of the trial, the concentrate was introduced in feeding routine. The concentrate was a mixture of pellets, crushed barley, corn flakes, sunflower seeds and linseed. The concentrate was fed separately to each mare. During feeding, the mares were separated by a fence so that they did not push each other through the feeder and each received exactly the same amount of feed. They received the same amount of concentrated feed on all days, depending on the individual mare (Tab. 2).

Mare	**Time of feeding (hr)**	**Type of forage**	**Amount of feed (kg)**	**Feed residue (g)**
Boni	8.01	Hey	3.6	0
	18.01	Hey	3.6	0
	18.01	Concentrate	1.3	0
Astrid	8.00	Hey	5.0	0
	18.00	Hey	5.0	0
	18.00	Concentrate	1.8	0
Afrodita	8.00	Hey	6.3	0
	18.00	Hey	6.3	0
	18.00	Concentrate	2.2	0

Tab. 2. Feeding management of mares in second trial period.

The composition of the concentrate was the same for all mares, namely: Barley flakes (20.0 %), corn flakes (20.0 %), wheat bran (15.0 %), oat bran (12.0%), beet molasses noodles, dried (12.0 %), maize gluten (6.5 %), wheat feed flour (5.5 %), beet molasses (4.0 %), calcium carbonate (2.0 %), sodium chloride (0.8 %), monocalcium phosphate (0.7 %).

2.3 *Behavioral measurements and data preparation*

As already mentioned, the EWS (Itin and Hoch, GmbH, Liestal, Switzerland) was used in our study to measure daily feed intake and chewing activity in horses. The mares had no previous contact with these noseband sensors, so adaptation period was introduced 4 days before the start of the experiment. At the time of installation, the sensors were installed according to the manufacturer's instructions. The noseband sensors were placed in the correct position and adjusted to the shape of each mare's head (Fig. 3). All four mares were fitted with EWS for continuous data collection throughout the duration of the trial.

Fig. 3. RumiWatch noseband sensors (Ferlez, 2024).

Raw data was transferred from the noseband sensor loggers via the built-in micro-USB port and connected USB cable. Raw data were converted from ‘.RAW’ filename extension (automatically generated by the software) to ‘.CSV’ filename extension by means of the RumiWatch Converter. In this study, we used RumiWatch Converter version 7.4.15, which algorithms are design for process data for horses (Steinmetz et al., 202). The feeding behavior and chewing of horses is different from cattle, which are ruminants, and other versions of the converter would not be suitable for data processing. The basic concept of the RumiWatch algorithm is to generate four classifications for parameters of ingestive behavior based on the noseband sensor pressure data. The mentioned RumiWatch Converter version 7.4.15 contains algorithms specifically designed to process data for horses.

Data were processed to generate 1-minute and 24 hour summaries of feeding behavior parameters.

The automatic quantification of the chewing activity was determined by pressure peaks, as reported by Werner et al., (2018). Every peak above the threshold of 28 mbar was counted as a chew. That means precisely, that not the height of a peak determined the chewing activity but the frequency of peaks. In this study, there was no differentiation between chews and bites.

With the converter, we monitored and compared the next feeding behavior parameters (Tab. 3): *total feeding time* (hr/d), *total chews* (n/d), *chew rate* (chews/min), *bouts* (n/d), *bout duration* (min/bout) and *other jaw movements* (n/d).

Feeding behavior variable	**Definition**
Total feeding time (hr/d)	Time spent intake (EATDOWNTIME and EATUPTIME), chewing, and swallowing of feed. Eating parameter is define: more then 30 jaw movements per minute, unsteady frequency.
Total chews (n/d)	Overall number of eating jaw movements (EATDOWNCHEWS and EATUPCHEWS). Chew parameter is deine: The system algorithms as the number of chews conducted with the head in either the down or up positions.
Chew rate (chews/min)	Number of chews within the time frame.
Bouts (n/d)	Parameter of GRAZEBOUTSTART and GRAZEBOUTFINISH indicate that a grazing bout has commenced or ended. The EWS software defines a grazing bout as a period of grazing activity extending for a minimum of 7 minutes with an interbout interval of 7 minutes.
Bout duration (min/bout)	The total time of an individual grazing bout.
Other jaw movements (n/d)	Chews not attributable to any ruminating, feed intake or drinking activity.).

Tab. 3. Variables of RumiWatch noseband sensors.

2.4 Statistical analysis

Statistical analysis was performed with the statistical software package SPSS 25.0. GLM. Since the studied parameters (*total feeding time, total chews, chew rate, bouts, bout duration* and *other jaw movements*) were not normally distributed, we used non-parametric methods/tests in the analysis. We performed a comparison between the two treatments groups - feeding with hay and feeding with hay and concentrate. We used the Mann-Whitney U test.

In the next step, we made a comparison between the two treatments over the course of the day, namely with regard to the *total feeding time* and the *chewing rate*. For this purpose, we made two-hour blocks and within each block and treatments were compared with the Mann-Whitney U test. Finally, we compared the treatments directly before and after feeding, namely we compared the appointment two hours before the morning and evening feeding (Two hours BEFORE) and the appointment two hours after the morning and evening feeding (Two hours AFTER). For this analysis, we used the general linear model procedure, including treatment (hay, hay with concentrate), term (two hours BEFORE, two hours AFTER) and their interaction as fixed effects.

3. Results

Daily feeding behaviors (as evaluated using the EWS) of horses maintained on the two different forage treatments (hay and hay+concentrate) are summarized in Tab. 4.

Regarding the total feeding time, the median between the two feed types showed that there were no significant differences (p = 0.439), indicating that the addition of concentrates to the diet had no significant effect on the daily feeding time. The results showed that there were no significant differences between the two treatments in the number of chews (p = 0.787), chew rate (p = 0.491), number of bouts (p = 0.787) and the bout duration (p = 0.158).

Feeding behaviour	**Hey**			**Hey and concentrate**			**Mann Whitney U**
	Me	*Q1*	*Q3*	*Me*	*Q1*	*Q3*	*p*
Total feeding time (hr/d)	9.08	6.99	10.83	9.27	8.93	9.66	0.439
Total chews (n/d)	37,136	28,308	44,837	37,164	35,055	39,206	0.787
Chew rate (chews/min)	54.36	50.38	6.00	54.65	48.54	58.28	0.491
Bouts (n/d)	12.01	9.54	15.32	12.57	11.06	13.02	0.787
Bout duration (min/bout)	48.13	45.47	44.63	49.33	53.94	48.84	0.158
Other jaw movements (n/d)	7,346	5,621	8,989	9,580	8,131	10,380	0.005

Tab. 4. Daily feeding behaviors of mares fed with hay and hay+concentrate during the test period.

Conversely, the number of other jaw movements classified as non-feeding related behaviors in horses receiving concentrates exceeded those reported during hay treatment (p = 0.005). When treated with hay, the median showed 7,346 other jaw movements/day, and when mares received hay and concentrate, the median showed 9,580 other jaw movements per day. The addition of the concentrate therefore had an effect on the number of other jaw movements, which can be explained by the fact that the concentrate has a looser texture, requiring the horse to make more movements, but this did not affect the number of total chewing movements or the chewing rate.

A 24-hour comparison of feed intake in mares is shown in Figure 4. The data show an expanded plot of the 24-hour variation when the mares were fed hay only compared to the treatment where concentrates were added. In order to statistically compare the data, we had to create time blocks of two hours. This allowed us to statistically compare the time blocks with each other.

The period with the highest total feeding time activity is observed in the morning and late afternoon (for hay 45.4 ± 15.1 min/h, for hay with concentrates 50.3 ± 8.7 min/h). The two highest time periods coincide with feed laying and the time immediately after feed laying, which explains the highest results in these time blocks. The lowest consumption was recorded between 2:00 and 6:00 am, with the lowest consumption in the 6:00-8:00 am time block (for hay – 6.4 ± 7.3 min/h, for hay with concentrates 3.70 ± 4.79 min/h). Differences occurred in the time block between 16:00 and 18:00, where a higher intake was observed when the mares received only hay. Differences also occurred during the night between 22:00 and 24:00. In this time block, the total feed intake time was higher when the mares received hay and concentrates.

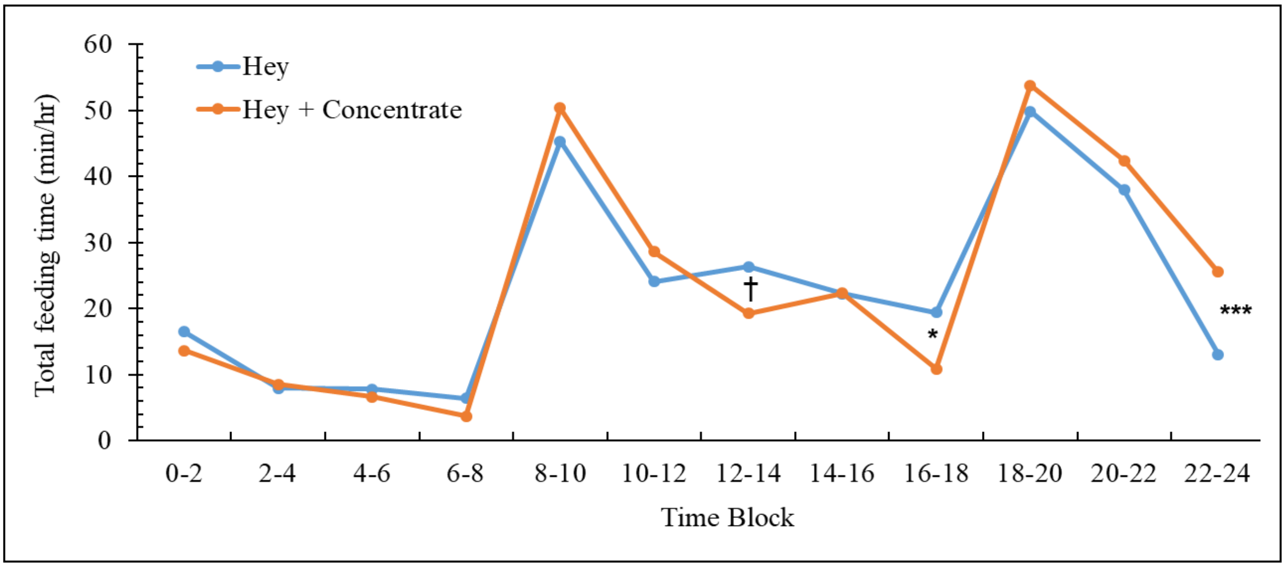

Fig. 4. Twenty-four-hour feeding patterns of total feeding time (min/hr) in mares fed with hay and hay+concentrate feeding period.

With regard to the chew rate (Fig. 5), it was found that the highest chew rate was recorded in the time block between 8:00 and 10:00 (for hay 70.34 ± 4.47 chews/min; hay+concentrate 67.91 ± 5.00 chews/min) and between 18:00 and 20:00 time block (73.69 ± 5.37 chews/min for hay; 70.87 ± 4.98 chews/min for hay+concentrate). Thus, the highest values were observed at the time when the mares were fed.

Differences were observed between the 22:00 and 24:00 time blocks ($p < 0.05$), where the chew rate was higher when the mares were fed hay+concentrate. After midnight, the rhythm of chew rate drops in this test period and increases in the period when the mares were fed hay only.

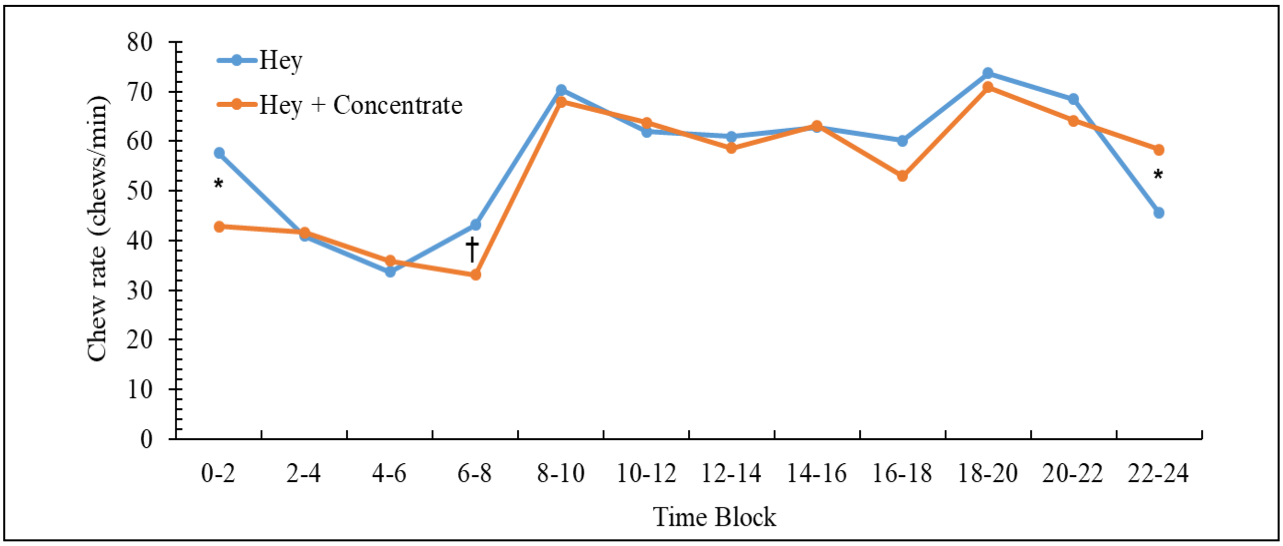

Fig. 5. Twenty-four-hour feeding patterns of chew rate (chews/min) in mares fed with hay and hay+concentrate feeding period.

To compare the results, we also performed a statistical analysis two hours BEFORE and two hours AFTER the time of laying the feed (Fig. 6).

The results show significant differences in the total feeding time BEFORE feeding the ration ($p < 0.05$; Fig. 6A). During this time, mares spent 13.3 ± 1.5 min/hr on feed intake when fed hay only, compared to only 7.3 ± 1.8 min/hr when fed hay+concentrate. There were no significant differences in total feeding time two hours AFTER the forage was fed, yet total feeding time AFTER was higher than BEFORE feeding, as expected and shown by previous results (for hay 47.8 ± 1.5 min/h, for hay+concentrate 52.1 ± 1.8 min/h).

Figure 6B compares the results of the other jaw movements between the two types of feed. Significant differences were observed within two hours AFTER feeding. When fed hay+concentrate, an average of 246.3 ± 33.2 other jaw movements were detected in the mares AFTER feeding, while only 149.8 ± 28.3 other movements were detected during the period when only hay was fed. Interestingly, the total number of other jaw movements before feeding was higher.

Figure 6C compares the total number of total chews. Significant differences were observed in the two hours BEFORE feeding. During hay feeding, an average of 900.61 ± 120.63 chews/min were recorded, while only 469.02 ± 139.29 chews/min were recorded during hay+concentrate feeding. There were no differences between hay (3,487.25 ± 118.78) and hay+concentrate (3,636.92 ± 139.29) AFTER feeding time.

Figure 6D compares chew rate between the two types of feed. The chew rate was significant different two hours BEFORE the feeding. When the mares were fed only hay, the chew rate was 52,12 ± 2,24 chews/min BEFORE the feeding, while we added concentrate to the mares, the chew rate was 43,00 ± 2,84 chews/min.

No significant differences were detected in chew rate between hay and hay and concentrate AFTER the ration, hay 73,69 ± 5,37 chews/min; hay+concentrate 70,87 ± 4,98 chews/min.

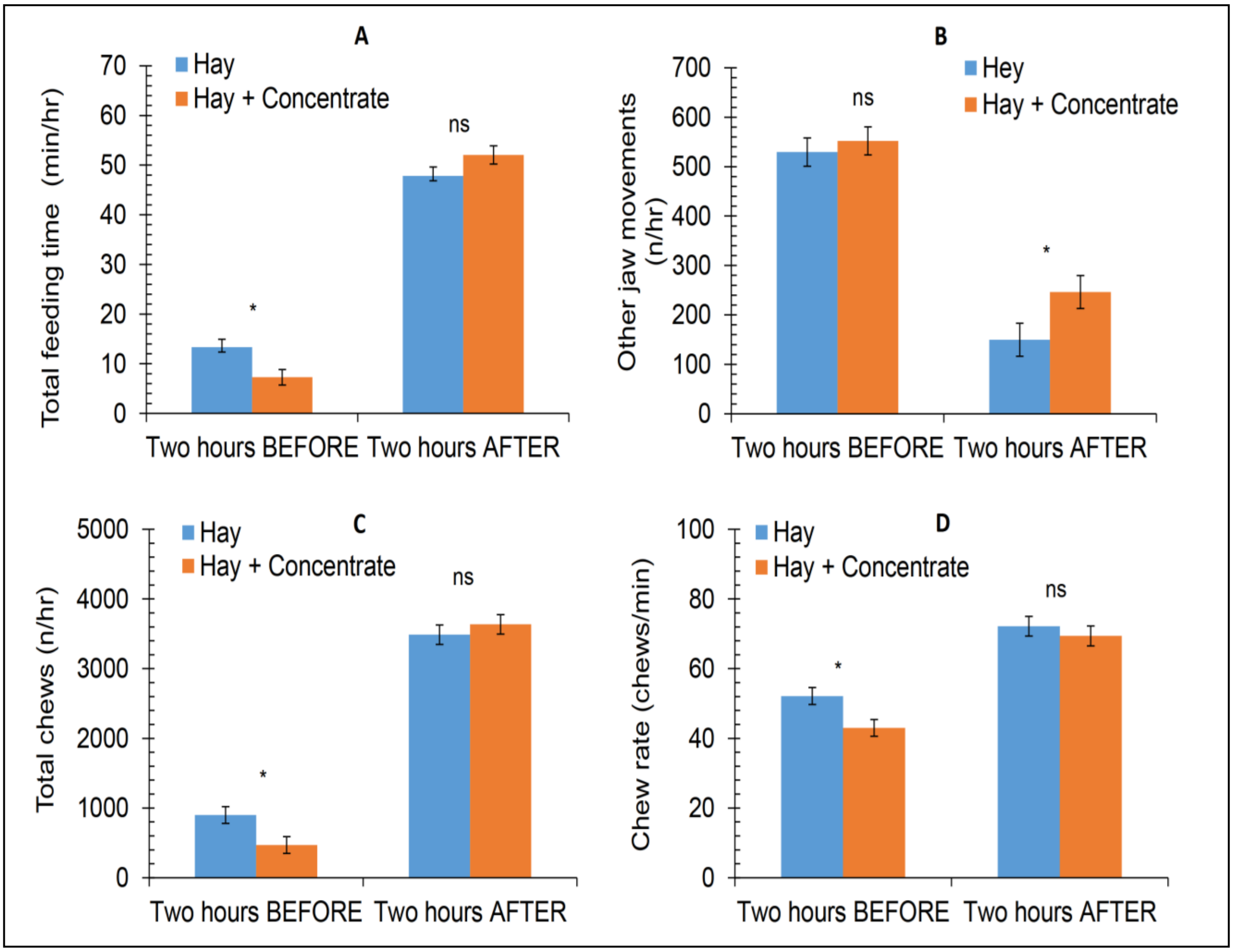

Fig. 6. Results comparison of the research period hay and hay+concentrate two hours BEFOR and AFTER forage feeding.

4. Discussion

Studies of feed intake in horses can be divided into field observations, which assess grazing behavior, and the assessment of voluntary feed intake (Matsui et al., 1990). This behavioral analysis is crucial for developing more effective herd management strategies and improving animal welfare by adapting their living conditions to their natural preferences and behaviors (Beaver & Höglund, 2015). Until now, various techniques have been used to automate grazing behaviors with an average accuracy of over 90 % compared to observations, providing valuable tools to study and monitor these activities of animals (Andriamandroso, et al., 2016). Noseband pressure sensors allow the estimation of time spent eating and the number and frequency of chewing and biting in both indoor and outdoor animals.

One of our goals was to evaluate the usefulness of the developed RumiWatch system in studies on the feeding behavior of horses. In this context, we first try to compare our results with other similar studies and measurements.

We emphasize that only two previous studies have used the same RumiWatch sensors in horses, and even they only addressed the issue of validating the system. The study by Werner et al. (2016) was the first study to investigate the feasibility of the “RumiWatch system" in horses.

The results of the visual observation were compared with the automatic measurement to evaluate the accuracy of the automatic measurement system. The study observed intervals of 10 minutes, but did not cover the entire daily rhythm and observation of feeding behavior. The study reported that the overall agreement of the observed and automatically measured data was 93 % for all feeds. When feeding roughage, the agreement was even higher at 95 %. However, the system has since been further adapted and optimized to improve accuracy. In the same study, the RumiWatch sensors detected 76.45 chews/min after the horses were fed hay (10 minutes after feeding). In our study, we recorded 73.69 chews/min for hay after feeding, which is consistent with the study presented.

Our aim was also to analyze the feeding behavior of the mares, to illustrate the daily feeding routine and to compare the differences in chewing activity when different feedstuffs were added. Our results are in the range of the values of the second study with the RumiWatch system in horses. Werner et al. (2020) compared the feed intake of horses kept in separate pastures, with one group receiving only hay and the other group having access to two rotational grazing sections in the pasture. They also used the RumiWatch system adapted for horses. In the study mentioned, it is reported that the horses spent an average of 11.98 hours on feed intake, while in our study the average time spent on feeding was 9.08 hours, which is slightly lower. Comparing the data on hay consumption and monitoring, the mentioned study also found low activity in feed consumption in the early morning hours (00:00 - 8:00) and around 12:00 (noon). Our data are also consistent in terms of the number of chews per day, the number of bouts per day and especially other jaw movements.

Other studies used different monitoring devices or observed the horses directly by direct or video observation. Ellis (2010) found that free-ranging horses typically had 10-15 distinct feeding bouts per day. Although our horses were not free-ranging, the number of feeding bouts was similar to our study.

We assumed that the chewing rhythm (rumination rate) would differ between the different feed types according to the different structure of the feed. Surprisingly, we found no difference in the general daily rhythm. The same was reported by Ellis (2010). The chewing rhythm (chews/min) remained fairly constant for each animal on different forage, while intake rates (g/min) adjusted according to moisture content, fracture properties, dental condition and organoleptic perceptions (Ellis, 2010). The number of chews by hay and concentrate was investigated by Meyer et al. (1975). A range of 3,000-3,500 chews/kg DM was determined for hay. The mean value for straw was 3,645 chews/kg DM and for concentrates a range of 832 chews kg/DM (oats) to 1,383 chews kg/DM (mixed concentrates) was given. Grinding oats led to an increase in chews/kg. For all feeds, the electronic recording system reported approximately 80-85 chews per minute, suggesting that the horse changes its intake rate according to feed texture while maintaining the chewing rhythm (Meyer et al., 1975).

Factors affecting ingestion behaviour (chewing, swallowing, length of bouts, choice of feed) are physico-chemical and organoleptic properties of the feed (particle length, elasticity, fracture properties, moisture, flavour and volume) or animal factors such as age, temperament, previous experience, preferences, dental condition, physiological condition (Ellis, 2010).

Modern horse management differs from that of the past and often involves keeping horses in stalls, feeding limited amounts of forage and feeding large amounts of concentrates at a limited number of times a day. Here, the horse is completely dependent on people regarding the time, choice and type of feeding (Direkvandi et al., 2016). Horses on pasture spend at least 8 to 12 hours per day feeding in order to consume enough forage to meet their nutritional requirements. When horses are fed in stables, the feed distribution pattern usually depends on the type of feed and the way it is distributed (Hallam et al., 2012). In *ad libidum* feeding, the amount of time spent feeding is usually similar to that of outdoor horses, but can be drastically reduced to as little as 20 % of the day if other supplements such as concentrates are added to the rations (Elia et al., 2010). For horses kept indoors, the behaviour associated with feeding is also different. With increasing nutritional and social constraints (horses are usually housed in individual boxes) and with feed available at all times, horses spend less time eating and more time standing (Thorne et al., 2005). Therefore, we would expect horses to have a very different time and regime for consuming different feeds. However, in our study, the time required for feeding did not change when we introduced concentrates in the feeding routine. A similar observation was also made in the study by Direkvandi et al. (2016). In the mentioned study, the time of feed intake of hay and hay with concentrates by Turkmen horses was investigated. For concentrate intake, the mean values for chewing and swallowing as well as the total intake time showed no clear differences for the same parameters when hay was consumed.

The data presented in in the results and discussion showed that the developed EWS monitoring sensory system, primarily developed for monitoring rumination, was successful in monitoring feeding behavior in horses. The system was designed to meet the requirements of scientific users. It allows us recording of ingestive behavior types with full raw data accessibility and post-processing option. The continuous sensor measurement of animal behavior holds great potential for a better understanding of animal behavior and for future studies.

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