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Introduction to automatic forage stations and measurement of forage intake rate in an active open barn for horses

L. Kjellberg [a,b,*,1], K. Morgan [a,b,1]

[a] Swedish National Equestrian Centre Strömsholm, Stallbacken 6, SE-734 94 Strömsholm, Sweden
[b] Department of Anatomy, Physiology and Biochemistry, Swedish University of Agricultural Sciences, Box 7011, SE-750 07 Uppsala, Sweden

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ABSTRACT

Interest in the use of open barns on Swedish horse farms is increasing as an alternative to keeping horses in box stalls and as a 2007 law requires phasing out of tie stalls. To provide adequate forage to satisfy welfare requirements for nutrition, gut health and behavioural needs, the use of automated feeding is also increasing. Studies on forage intake rate report wide variation but provide little information on how to introduce horses to an automatic forage station and on how forage intake rate varies in individual horses fed using an automatic forage station. This study documented the process of training 22 horses to use a transponder-controlled automatic forage feeding station and measured forage intake rates. Observations on the learning period of horses for transponder-controlled automatic forage stations showed that after 4 days, 48% of the horses had reached the goal of 90% intake. After 8 days, learning was completed in 71% of horses and at 16 days in 95% of horses. Measurements of forage intake rate revealed significant differences between individual horses. Overall mean intake rate ± SD, based on 314 observations, was 22.4 ± 6.7 min/kg forage DM. Evaluation of the number of intake measurements required to set a representative average ration in the automatic station for an individual horse showed that the variation levelled off at four samples. In conclusion, horses quickly learned how to use an automatic forage station, with two-thirds of horses achieving this within 7 days. To ensure the correct ration in a timed transponder-controlled automatic forage station, each horse's forage intake rate must be measured at least four times to obtain a representative average.

Implications

This study showed that horses can quickly learn to use timed transponder-controlled automatic forage stations, with two-thirds of horses reaching the goal of 90% intake within a week of stepwise introduction. Measurements of forage intake rate revealed differences between individual horses, with an overall mean value of 22.4 min/kg DM haylage. Considering the variation within individual horse samples, when setting the ration in an automatic station, each horse's forage intake rate should be measured at least four times to obtain a representative individual mean value.

Introduction

Horse welfare has become a key issue in horsekeeping in Sweden. The Swedish Board of Agriculture (2018) estimates that the current housing system comprises 75% individual boxes, 20% open barns and 5% tie stalls. There is increasing interest in keeping horses in open barns, both for welfare reasons (Fors-Jadin and Wännman Kvantenå, 2017) and because of legislation banning tie stalls in new or renovated stables since 2007 (Swedish Animal Welfare Agency 2007 [Ch. 3, § 4 DFS 2007:6]). An open barn is defined as a loose-housing system with a paddock, a lying hall with bedding and *ad libitum* or restricted feeding. *Ad libitum* feeding of forage to leisure horses can result in obese horses, which can cause problems such as laminitis and equine metabolic syndrome (Chapman, 2014). To avoid these problems, automatic feeding stations that control access to individual feeding, using a time-based system, have been developed. The system is called active open barn, and there are currently 35 such facilities in Sweden.

Studies on forage intake rate show great variation between individual horses, with the time taken for intake of 1 kg of hay DM varying from 38 to 74 min in different studies (Dulphy et al., 1997; Harris et al., 2005; Brøkner et al., 2008). Intake of silage is reported to vary from 29 to 47

* Corresponding author at: Swedish National Equestrian Centre Strömsholm, Stallbacken 6, SE-734 94 Strömsholm, Sweden.
E-mail address: linda.kjellberg@rsflyinge.se (L. Kjellberg).
[1] Present address: Swedish National Equestrian Centre Strömsholm, Stallbacken 6, SE-734 94 Strömsholm, Sweden.

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min/kg DM in different studies (Müller, 2011; Abrahamsson, 2012). Müller (2011) also found that forage feed intake rate for haylage could also vary from time to time due to the harvest date. These results indicate that there is wide variation between individual horses, which must be considered in the management regime when allocating forage according to time.

There have been some previous studies on active open barns, concerning horse feeding behaviour around concentrate feeding stations (Hoffmann et al., 2012; Gülden and Büscher, 2017; Gülden et al., 2018). However, there is limited information on how to introduce horses to an automatic feeding station and how forage intake rate varies in horses using automatic individual forage stations. The aim of this study was to document the time needed to train the horses to autonomously manage a forage feeding station and to measure forage intake rates. The following research questions were addressed: How long does it take to train horses to use an automatic forage feeding station? How can individual forage intake rate be established for horses fed from an automatic forage feeding station?

Material and methods

Horses

The study was conducted at the Swedish National Equestrian Centre in Strömsholm, Sweden. All horses in the study were Swedish Warmblood geldings, aged 3–18 years. They are all used as school horses in the undergraduate programme in equine studies at the Swedish University of Agricultural Sciences. The horses were divided into two age groups, older (≥7 years) and younger (3–6 years). The older horses are trained to compete in dressage (advanced M-level) or showjumping (1.2–1.3 m). The younger horses are being trained in dressage or showjumping. All horses are exercised 5–6 times a week. The oral cavity of each horse is inspected and, if needed, corrected by a veterinarian once or twice a year.

Housing system

The horses were housed in either an active open barn system for 24 horses or in a single-box system (3 m × 3.5 m). Horses in boxes were fed manually four times a day (at 0630, 1130, 1600 and 2000 h) and spent 2–4 h in a paddock. The active open barn HIT Active Stable® (Weddingstedt, Germany) consisted of one paddock of at least 150 m^2 per horse and four lying halls with a total lying area of 23 m^2 per horse, mainly bedded with straw. For horses in the active open barn, haylage was served in a transponder-controlled automatic forage feeding station, HIT-double hay station type B, designed as double stations with a total number of six feeding stalls (Fig. 1). The individual feeding time of each horse was pre-programmed in a chip placed in a neck collar (Fig. 2). The horse enters the forage station via a rear gate that opens when the previous horse's feeding time is finished. When a horse enters the stall with feeding time left and has not been fed during the preceding 60 min, the rear gate closes and a partition wall is lowered in front of the horse. When feeding time for that session is used up, the partition wall is slowly raised, and the horse exits via a side-placed front gate. The horses were also offered straw *ad libitum*, in one hayrack, Horseking Safety HayRack. In addition, there were three automatic watering bowls, HIT-drinker Aqua, and one transponder-controlled automatic concentrate feeding station, HIT-concentrate feeder Kompakt.

Study 1: introduction of horses to an automatic feeding station

A total of 22 Swedish Warmblood geldings were introduced into the active open barn. These comprised a group of 14 older horses (aged 8–17 years) previously housed in a single-box system and a group of eight younger horses (aged 4–6 years) previously housed in a loose-housing system. All horses were fed haylage with 77% DM content and all had 300 min feeding time programmed each day, according to the manufacturer's recommendations and distributed into maximum 20 portions in each 24-hour period. When a horse left the housing system, a computer recalculated the remaining feeding times so the programmed feeding time was fulfilled during the remainder of the 24-hour period. During the first week of the study, only the automatic forage stations were in use, as installation of the automatic concentrate feeding station was delayed until the second week of the study.

One stable manager was responsible for the entire training period. Each horse was introduced to the automatic forage station with the assistance of a trainer in four steps: 1) approach the feeding stall (led initially), 2) learn how to find feed, 3) accept rear gate closing and 4) learn how to open the exit gate (Fig. 2). The stable manager decided when a horse was ready for the next step. The horses were trained by students under the supervision of the stable manager, so that up to six horses could be trained simultaneously. Each horse had the same student trainer for most of the time. The frequency of sessions per day depended on the number of available students. A protocol was established for each horse, recording how many training sessions were needed. A horse was considered ready to be released into the system when it had accepted the automatic forage feeding station and could perform the steps described above without assistance from the trainer. Recording of daily forage feeding time started as soon as the horse was released. A horse was considered to have learned the system when it reached 90% of its pre-programmed feeding time, calculated by the computer integrated in the system.

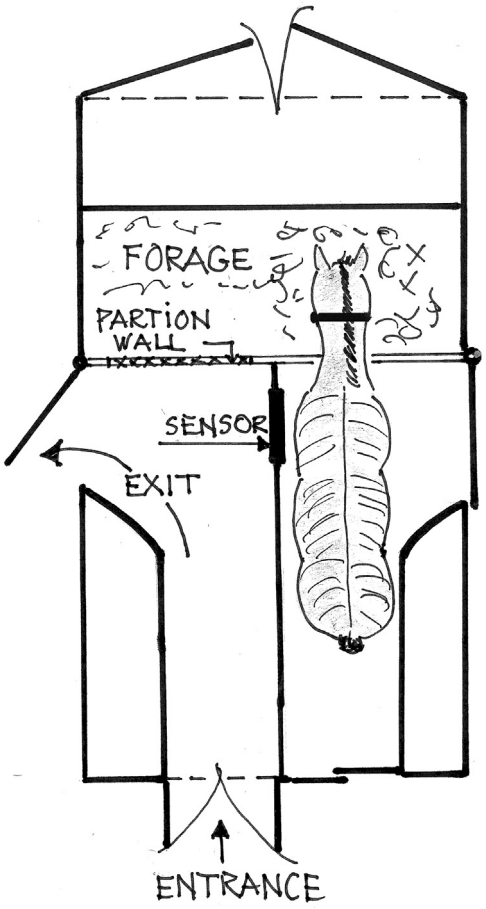

Fig. 1. An illustration of the transponder-controlled forage feeding stations, used in the study, displaying the horse's position and passage.

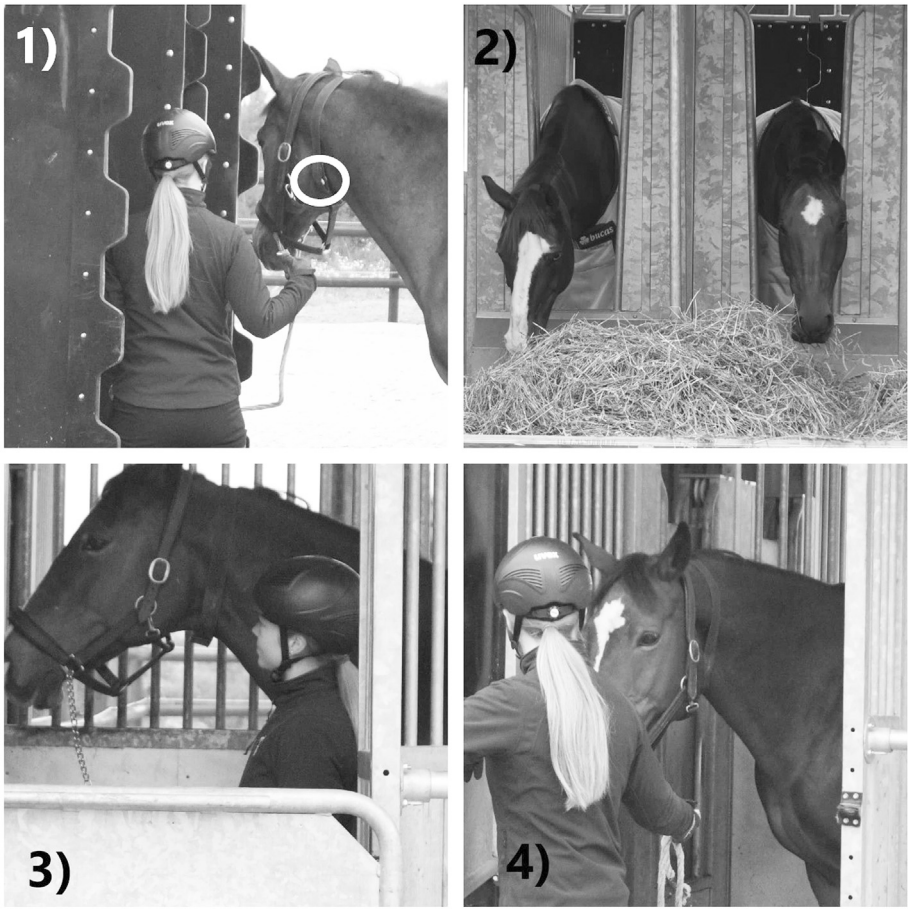

Fig. 2. The illustration visualizes the four steps of how to train a horse to use the automatic forage stations: 1) approach (led initially), 2) find feed, 3) accept closed doors behind, 4) open the exit gate. Photo 1 also shows the neck collar where the chip is placed (marked with a white circle).

Study 2: forage intake rate

Intake rate of haylage was measured in 28 Swedish Warmblood geldings in two consecutive sub-studies (2a, 2b). The BW of the horses varied between 510 and 700 kg, see Table 1. The horses were fed 110–145 MJ/day or 7.7–23.7 kg DM per day. All horses had been fasting for 2 h before measurement of forage intake rate began. They were all fed their usual haylage, the DM content of which was measured just before each sub-study by drying at 100 °C for 60 min in a TT Moisture tester from the company *Stallmästaren AB* (Lidköping, Sweden).

In study 2a, 20 horses were tested in pairs, 10 horses housed in an individual box system and 10 horses in an active open barn, to evaluate the effect of housing system due to different feeding regimes in individual boxes (4 times/day) and the active open barn (20 times/day). Measurements were performed in a series of eight tests, in a familiar room used for horse care. In each test, the horses were fed 3 kg of their usual haylage in a wide hay-bag for 20 min, divided into two 10-minute parts. After the first 10 min, the haylage in the hay-bag and waste from floor were weighed and then the horse was fed the remaining haylage in the same bag for another 10 min. After completing each feeding session, the remaining haylage including waste was weighed again and the forage intake rate for each horse was calculated in minutes per kg DM. Haylage DM was determined before each test (mean value ± SD of 79 ± 2%).

In study 2b, only horses housed in an active open barn were tested. Eleven geldings were tested in pairs in an automatic feeding station, in two series of seven tests comparing two methods to establish the most efficient way to measure the individual forage intake rate. In Method 1, the horses were fed 5 kg of their usual haylage for 15 min, and then the remaining haylage was weighed and the forage intake rate of each horse was calculated in minutes per kg DM. In Method 2, the horses were fed haylage corresponding to 1 kg DM and total feeding time to finish was measured. Seven repetitions were conducted for each method. Haylage DM was determined before each test and found to vary from 57 to 70% (mean 64 ± 3%).

Statistical analyses

In study 1, the two groups, older and younger horses, were compared with a Student's t-test for three parameters: total number of training sessions, number of training sessions per day and number of days to reach 90% of daily forage intake. For study 2, descriptive statistics on forage intake rate for the 28 individual horses in study 2a and 2b were calculated. A non-parametric model was used for comparisons since the data were not normally distributed, as shown in Fig. 3. Individual differences were compared using Kruskal–Wallis one-way ANOVA on ranks, followed by Dunn's test for post hoc test. A median was calculated for each horse before applying the Mann–Whitney rank sum test to compare differences in forage intake rate between 1) housing systems (2a), 2) Method 1 vs Method 2 (2b) and 3) age group (2ab). The Wilcoxon signed rank test was used for comparing forage intake rate between 0 and 10 min vs 11–20 min in study 2a. To establish the number of measurements needed to get a representative individual forage intake rate, an individual mean value for one to seven repetitions was first calculated. The difference in mean value between seven and six

Table 1
Characteristics (age, BW and daily forage ration) of the horses used in the study ($n = 28$) and individual forage intake rate (min/kg DM). There were significant differences between horse 1–11 vs horse 28, horse 1–5 vs 23–27 and horse 1–3 vs 21–22.

Horse no.	Age (years)	BW (kg)	Forage ration (kg DM)	Individual forage intake rate (min/kg DM)				No. of observations
				Mean ± SD	Median	Min – max	Range	
1	5	600	21.2	13.2 ± 0.4	13.3	12.6–13.7	1.1	$n = 5$
2	6	620	12.8	15.9 ± 3.7	15.4	11.5–23.6	12.1	$n = 8$
3	12	632	14.1	16.1 ± 5.7	13.9	12.6–29.8	17.2	$n = 8$
4	9	578	16.7	16.4 ± 4.0	14.9	13.7–26.0	12.3	$n = 8$
5	5	668	21.7	16.6 ± 3.1	15.7	13.6–23.2	9.5	$n = 8$
6	6	697	23.7	16.9 ± 1.8	16.6	14.5–19.5	5.0	$n = 8$
7	12	679	21.0	17.1 ± 5.9	15.3	12.7–31.1	18.4	$n = 8$
8	13	682	23.1	17.3 ± 2.7	18.2	14.1–20.5	6.4	$n = 8$
9	16	676	20.1	17.9 ± 4.5	16.5	14.7–28.3	13.6	$n = 8$
10	6	527	16.8	17.9 ± 2.6	18.1	14.1–22.0	7.9	$n = 8$
11	5	559	15.9	18.9 ± 3.2	18.3	16.0–26.4	10.4	$n = 8$
12	12	619	15.3	18.9 ± 5.4	17.7	14.2–30.3	16.0	$n = 8$
13	8	620	10.3	19.4 ± 2.4	18.4	16.7–24.0	7.3	$n = 14$
14	10	565	12.8	20.4 ± 3.7	19.6	15.3–26.9	11.6	$n = 8$
15	4	698	13.8	21.8 ± 6.9	19.8	16.8–37.2	20.4	$n = 8$
16	7.5	645	9.9	21.9 ± 5.0	21.3	14.6–34.9	20.3	$n = 22$
17	11	680	19.2	22.5 ± 2.3	22.3	19.5–27.1	7.6	$n = 8$
18	4	622	13.8	23.2 ± 3.2	22.4	18.9–30.1	11.2	$n = 14$
19	18	560	19.2	24.1 ± 5.5	24.3	17.6–31.8	14.3	$n = 8$
20	11	556	12.2	24.5 ± 5.0	23.7	18.2–38.0	19.8	$n = 14$
21	3	558	11.4	24.6 ± 2.9	24.7	17.9–28.6	10.7	$n = 14$
22	13.5	566	9.0	24.7 ± 5.2	24.0	17.2–38.9	21.7	$n = 22$
23	17	542	11.8	25.4 ± 3.4	24.3	21.7–32.2	10.5	$n = 14$
24	11	633	10.9	25.7 ± 6.5	24.6	18.6–45.4	26.8	$n = 14$
25	10	634	7.7	25.9 ± 5.2	25.1	18.8–39.5	20.6	$n = 14$
26	16	590	15.3	26.4 ± 9.3	23.3	20.7–48.7	28.0	$n = 8$
27	16.5	657	14.2	27.4 ± 9.5	25.2	17.6–61.2	43.6	$n = 22$
28	3	512	10.8	33.2 ± 7.7	32.8	20.0–51.2	31.2	$n = 14$

repetitions (1–7 vs 1–6), seven and five repetitions (1–7 vs 1–5) and so on was determined. The mean value and SD of the differences were then calculated for each set of repetitions. In combination, the correlation between seven repetitions and each set of sub-groups of repetitions (1, 1–2, 1–3, 1–4, 1–5, 1–6) was analysed.

SigmaPlot version 13.0 (Systat Software, 2014) was used for statistical analyses. The level of significance was set to $P < 0.05$. The results are presented as mean value ± SD and, when appropriate, the median.

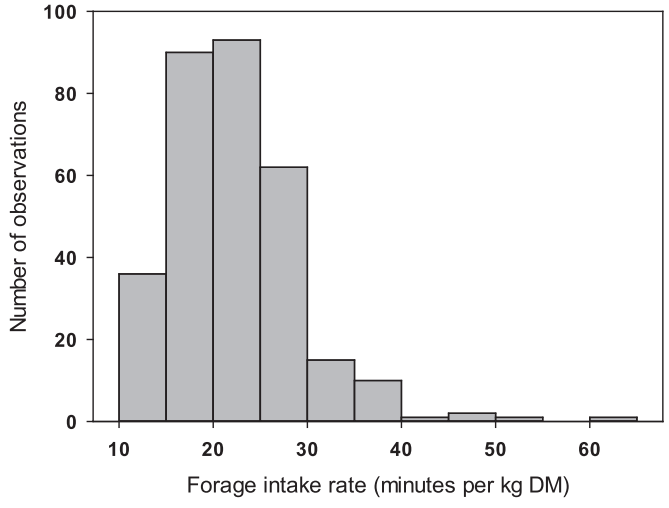

Fig. 3. The diagram shows the distribution of forage intake rates for the 28 horses in the two consecutive sub-studies (2a, 2b). There were in total 314 measurements where the number of samples from each individual varied ($n = 5$, 8, 14 or 22). The forage intake rate was measured either by recording the time to eat a fixed ration or by recording the eaten amount in a fixed time frame.

Results

Study 1: introduction to feeding station

After 4 days, 48% of the 22 horses in the study had reached the goal of 90% intake. After 8 days 71% of the horses had reached the goal, while at 16 days 95% had reached the goal. The younger horses needed a significantly ($P = 0.01$) fewer training sessions (11.8 ± 2.1) than the older horses (23.5 ± 11.5). However, it was noted that the younger horses trained for significantly ($P = 0.036$) more sessions per day (5.9 ± 1.0) than the older horses (4.7 ± 1.5). There was no significant difference ($P = 0.91$) in number of days taken to reach 90% of daily forage intake between the groups (younger horses: 7.3 ± 7.3 days, older horses: 7.8 ± 2.8 days).

Study 2: forage intake

The overall mean forage intake rate in both sub-studies (2ab, $n = 314$) was 22.4 ± 6.7 min/kg DM (ranging from 11.5 to 61.1). However, in the individual results, there were significant inter-individual differences ($P < 0.001$), see Table 1. No differences between groups were found for the parameters: 1) housing system ($P = 0.385$); active open barn (18.0 ± 4.3; median 17.4) vs the individual boxes (20.9 ± 7.9; median 18.8); 2) measuring method ($P = 0.948$); Method 1 (18.0 ± 4.3; median 24.4) vs Method 2 (20.9 ± 7.9; median 24.4); or 3) age group ($P = 0.331$); younger horses 3–6 years (21.7 ± 7.1; median 18.2) vs older horses 7–18 years (22.7 ± 6.5; median 22.3). In study 2a, the horses ate faster ($P < 0.001$) in the first period, 0–10 min of the test (17.8 ± 6.0; median 16.4) than in the remaining 10 min (22.2 ± 9.1; median 19.8).

There was some fluctuation in intra-horse forage intake rate when the measurements were repeated seven times. It was found that four to six repetitions gave an acceptable difference in mean value and SD in combination with a strong correlation ($R^2 \geq 0.88$) between seven

Table 2
Results of analysis to establish the number of measurements required to obtain a representative mean value of individual forage intake rate in horses. The mean value for seven measurements was compared with that for one up to six measurements. The values shown are mean ± SD of the difference compared with seven measurements, the correlation coefficient (R^2) and the equation.

Number of measurements compared	Difference mean ± SD	Correlation	
One (no. 1) vs all (no. 1–7)	−0.1 ± 4.2	$R^2 = 0.62$	y = 1.16x − 3.67
Two (no. 1–2) vs all (no. 1–7)	−1.5 ± 2.2	$R^2 = 0.79$	y = 0.92x + 0.17
Three (no. 1–3) vs all (no. 1–7)	−1.1 ± 1.9	$R^2 = 0.87$	y = 1.07x − 2.60
Four (no. 1–4) vs all (no. 1–7)	−0.6 ± 1.6	$R^2 = 0.88$	y = 0.92x + 1.21
Five (no. 1–5) vs all (no. 1–7)	−0.5 ± 1.4	$R^2 = 0.91$	y = 0.93x + 1.03
Six (no. 1–6) vs all (no. 1–7)	−0.1 ± 1.1	$R^2 = 0.94$	y = 0.99x + 0.10

measurements vs the actual series, see Table 2. Based on this analysis, we recommend at least four measurements to get a representative average for an individual horse.

Discussion

The first horses to learn to use the automatic forage station were horses considered to be easy feeders. This could be explained by findings by Olczak et al. (2018) that the degree of food motivation differs between individuals, which may affect how fast horses learn a new feeding routine. It was possible to release the younger horses into the system sooner than the older horses. This could possibly be due to more frequent training of the younger horses and the fact that they came from a loose-housing system and were accustomed to putting their head into a hayrack.

In the first week of the study, the concentrate feeding station was not in operation. This could have affected the time taken for the horses to learn how to use the feeding station. In the concentrate feeding station, the horse had to lower its head to be identified by its data chip and then rewarded by the ration of concentrate feed. When a horse had learned this, it made faster progress in learning to use the automatic forage feeding station. Palatable food, for example pelleted concentrate, has been shown to encourage quicker responses when horses are learning a new routine (Ninomiya et al., 2007). The concentrate feeding station seems to be important to encourage through-flow in the system (Hoffmann et al., 2012). An example of this was that during the first week, one of the older horses, considered by staff to be a high-ranking horse, monopolized one stall in the automatic forage feeding station. This behaviour ceased as soon as the concentrate feeding station was in full operation. Monopolizing time has been shown to decrease on reducing the number of portions to three per day (Gülden et al., 2018) and providing an acoustic signal followed by a compressed air stimulus (Gülden and Büscher, 2017).

The individual ration in forage stations for horses in an active open barn system is set according to available feeding time in minutes. Recommended feeding time when introducing a horse is fixed (300 min) and does not consider inter-horse differences in forage feed intake rate. In the present study (2a and 2b), the individual mean value varied from 13.2 to 33.2 min/kg haylage DM, see Table 1. It is therefore important to establish individual adjusted daily rations, since there are inter- and intra-individual differences in forage intake rate. According to previous studies, other factors may also affect the forage intake rate, such as harvesting method and harvest date. Haylage has been found to have a lower forage intake rate, for example, 29–47 min/kg DM (Müller, 2011; Abrahamsson, 2012), compared with hay, for example, 38–74 min/kg DM (Dulphy et al., 1997; Harris et al., 2005; Brøkner et al., 2008). Differences in forage intake rate between individuals were also found by Müller (2011), with ranges from 29 to 41, 34 to 65 and 35 to 64 min/kg DM for forages with different harvest dates. The overall mean value (22.4 ± 6.7 min/kg DM) in our study indicated lower forage intake rate for haylage compared with other studies (Müller, 2011; Abrahamsson, 2012). An explanation for the differences between studies could be differences in fibre content, since the horses in our study and those in Müller (2011) and Abrahamsson (2012) were of the same size and type. The highest value observed in this study, 61.2 min/kg DM, was recorded for a horse that was very distracted by the surroundings and had difficulty focusing on feeding, which prolonged the feeding time on the measurement occasion. This can happen when one individual is feeding in the forage feeding station and is a factor to consider when programming the feeding time. No prior inspection of the oral cavity was done in the present study, but all horses at the facility are checked regularly. It is thus possible, but unlikely, that oral problems influenced the forage intake rate in the studied horses.

We compared two different methods for measuring forage intake rate. The horses showed the same forage intake rate when fed *ad libitum* for 15 min (Method 1) or given 1 kg DM and allowed to finish (Method 2). Method 1 was more labour-intensive due to more steps, because the forage needed to be weighed twice (before starting and all leftovers), which also may create more sources of error. However, Method 1 was usually faster (15 min), especially if the horse ate slowly (>15 min). According to the results obtained, both methods were equally valid and showed the same measurement patterns. A common pattern with both methods was high variation within the series of measurements. Thus, making only one measurement for a horse and following the automatic station manufacturer's recommendation of 300 min feeding time per day could lead to forage intake of the individual horse varying from 5 to 25 kg DM per day. This means that several measurements are needed to get a relevant average for each horse. After four measurements, the variation in mean value was more consistent within a horse and can be used when introducing a horse to the system. However, it is important that the stable manager monitors the horse over time and adjusts the feeding time when required.

Conclusion

Horses quickly learned to use an automatic forage station, with two-thirds of the horses studied learning the system within a week. We recommend at least four measurements to establish a representative mean value for setting the correct ration in a timed automatic forage station for an individual horse.

Ethics approval

All experimental procedures involving animals were approved by the local ethics committee, according to Swedish legislation (SJVFS 2019:9), dnr C 80/15.

Data and model availability statement

None of the data have been deposited in an official repository.

Author ORCIDs

Linda Kjellberg (0000-0002-9588-726X) and Karin Morgan (0000-0003-1358-5709).

Author contributions

Kjellberg has written the manuscript with supervision of Morgan. The authors had joint responsibility for data collection and revision of the manuscript. Morgan performed the statistical analysis with statistical advice from von Brömssen. Morgan has drawn the illustration in Fig. 1.

Declaration of interest

The authors declare they have no conflicts of interest.

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