Institut für Landtechnik

Investigation of the feeding process at concentrate feeding stations for horses in group housing

Dissertation

zur

Erlangung des Grades

Doktorin der Agrarwissenschaften

(Dr. agr.)

der Landwirtschaftlichen Fakultät

der Rheinischen Friedrich-Wilhelms-Universität Bonn

von

Aline Gülden

aus Düren

Bonn 2018

Referent: Prof. Dr. Wolfgang Büscher

Korreferent: Prof. Dr. Karl Schellander

Tag der mündlichen Prüfung: 29.03.2018

Angefertigt mit Genehmigung der Landwirtschaftlichen Fakultät der Universität Bonn

Diese Dissertation ist auf dem Hochschulschriftenserver der ULB Bonn unter http://hss.ulb.uni-bonn.de/diss_online elektronisch publiziert.

Die vorliegende Arbeit wurde durch die Mehl-Mülhens-Stiftung gefördert und in Kooperation mit der Firma Schauer Agrotronic GmbH durchgeführt.

Meiner Familie

Abstract

Computer-controlled concentrate feeding stations are increasingly used to guarantee an individual feed supply of group-housed horses. Blocking times caused by horses remaining in the feeding station without concentrate allowance are classified as a widespread problem in practice. To date, stimulation devices applying an electric impulse seem to be the only reliable means to prevent these blocking times efficiently. However, the scientific community describes the application of an electric impulse to force the horses to leave the feeding station as incompatible with animal welfare considerations.

The aim of the present study was to optimise the feeding process at concentrate feeding stations for horses in group housing. The optimisation primarily focused on the prevention of blocking times caused by horses without concentrate allowance. The studies were conducted at a concentrate feeding station operated at a horse farm under common practice conditions.

The first study examined the effectiveness of an innovative stimulation device in preventing the occurrence of blocking times. For this purpose, an apparatus was developed which applied compressed air between the horses' hind legs. The behaviour of 16 horses was observed over a period of 3 x 24 h in each of the four trial periods. Initially, the blocking behaviour of the horses could be reduced significantly by the application of compressed air. The increase of the horses' average daily blocking duration and blocking frequency in the course of the test series indicated the occurrence of a habituation effect over time.

The second study examined if the feeding management implemented at a concentrate feeding station influences the horses' blocking and activity behaviour. The behaviour of 19 horses was observed over a period of 3 x 24 h in each of the three trial periods (1. 24-hour feeding; 2. Daytime feeding; 3. Three feeding times). The implementation of three feeding times reduced the horses' blocking frequency as well as the blocking duration significantly. Furthermore, it could be observed that the horses' activity behaviour was highest with the application of three feeding times. Nevertheless, the adjustment of the feeding frequency did not reliably prevent the occurrence of blocking times.

The present thesis contributes to the development and improvement of concentrate feeding stations for horses in group housing. It has become obvious that the emergence of blocking times is a very complex issue and that the use of concentrate feeding stations goes far beyond the simple utilisation as a feeding device. Against this background, practical recommendations for action as well as further research focuses are pointed out in the present thesis.

Kurzfassung

Computergesteuerte Kraftfutterabrufstationen werden zunehmend eingesetzt, um eine tierindividuelle Kraftfutterversorgung von Pferden in Gruppenhaltung zu gewährleisten. Die Blockade der Futterstationen durch Pferde ohne Futteranspruch stellt in der Praxis allerdings ein weit verbreitetes Problem dar. Der Einsatz stromführender Austreibhilfen wird in er Wissenschaft als nicht tierschutzkonform eingestuft, scheint aber derzeit die einzige Möglichkeit zu sein, das Auftreten dieser Stationsblockaden effizient zu verhindern.

Ziel der vorliegenden Arbeit war es, den Fütterungsablauf an Kraftfutterabrufstationen für Pferde in Gruppenhaltung zu optimieren. Die Optimierung bezog sich insbesondere darauf, das Auftreten von Stationsblockaden durch Pferde ohne Futteranspruch zu verhindern. Alle Untersuchungen wurden auf einem Praxisbetrieb durchgeführt, der eine Kraftfutterstation unter praxisüblichen Bedingungen zur Kraftfutterversorgung der Pferde einsetzt.

In der ersten Studie wurde die Effizienz eines innovativen Austreibsignals in der Vermeidung von Stationsblockaden untersucht. Zu diesem Zweck wurde eine Druckluftapparatur für die Applikation eines Luftstromes entwickelt. Der Luftstrom traf die Pferde bei Aktivierung zwischen den Hinterbeinen. In insgesamt vier Versuchsphasen wurde das Verhalten von 16 Pferden über einen Zeitraum von jeweils 3 x 24 h beobachtet. Das Blockadeverhalten der Pferde konnte durch den Drucklufteinsatz zunächst signifikant reduziert werden. Die Zunahme der durchschnittlichen Blockadezeit und -frequenz im Verlauf des Versuchszeitraumes lässt allerdings das Auftreten eines Gewöhnungseffektes erkennen.

In der zweiten Studie wurde untersucht, ob das Fütterungsmanagement an einer computergesteuerten Kraftfutterabrufstation das Blockade- und Aktivitätsverhalten von Pferden beeinflusst. In insgesamt drei Versuchsvarianten (1. Fütterung über 24 h; 2. Fütterung nur tagsüber; 3. Drei Fütterungszeiten) wurde das Verhalten von 19 Pferden über einen Zeitraum von jeweils 3 x 24 h beobachtet. Durch die Einführung von drei Fütterungszeiten konnten sowohl die Blockadefrequenzen als auch die Blockadezeiten der Pferde signifikant reduziert werden. Darüber hinaus wurde festgestellt, dass das Aktivitätsverhalten der Pferde unter der Anwendung von drei Fütterungszeiten am höchsten war. Dennoch konnte die Anpassung der Fütterungsfrequenz das Auftreten von Stationsblockaden nicht verhindern.

Die vorliegende Arbeit leistet einen wesentlichen Beitrag zur Weiterentwicklung computergesteuerter Kraftfutterabrufstationen für Pferde in Gruppenhaltung. Es wird deutlich, dass es sich bei der Entstehung von Stationsblockaden um einen sehr komplexen Sachverhalt handelt und der Einsatz von Kraftfutterabrufstationen weit über die einfache Nutzung als Fütterungseinrichtung hinausgeht. Vor diesem Hintergrund werden praxisnahe Handlungsempfehlungen ausgesprochen und weiterführende Forschungsansätze aufgezeigt.

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Abbreviations

A	Acoustic signal
ALT	Activity, Lying time, Temperature
CA	Compressed air
CFS	Concentrate feeding station
D	Drinker
f	Feeding portion
Max.	Maximum
Min.	Minimum
p	Level of significance
RFID	Radio-frequency identification
s.d.	Standard deviation
SG	Selection gate
T	Touch trigger

1 General Introduction

Keeping horses in groups is a topical subject in horse husbandry. Due to the recommendations of the German Federal Ministry of Food, Agriculture and Consumer Protection (BMELV, 2009), horses should be kept in groups wherever possible. The national evaluation framework for livestock management systems (Eurich-Menden, 2006) gives an overview of the different housing systems available for horses in practice.

A great variety of different housing systems offers the opportunity to keep horses in groups (Hartmann et al., 2012). Among them, the management of horses in so called active barns becomes increasingly popular in modern horse husbandry. This stable design is characterized by a generous space offer and the spatial separation of the different functional areas (Rose-Meierhöfer et al., 2010). According to Vervuert and Coenen (2002), the general establishment of active barns is only a question of time because this housing system satisfies the horses' basic needs for locomotion, continuous feed intake and social contact best. Therefore, active barns essentially contribute to the horses' health. Furthermore, a larger number of horse owners want to keep their horses under species-appropriate conditions (Hoffmann et al., 2012). It is particularly pleasing that increasingly more farm managers want to satisfy this request.

Due to age, breed and training condition, the feeding requirements of the horses housed together in one group usually differ. To guarantee an individualised feed supply for all horses, the use of feeding stalls is recommended (BMELV, 2009). As these can be replaced by alternative measures, the use of automatic feeding systems becomes more and more popular to meet the different feeding requirements in heterogeneous horse groups (Streit et al., 2008; BMELV, 2009).

The individualised and time-controlled feeding process is described as the decisive advantage of automatic feeding stations for horses. Furthermore, the technical support to control the concentrate intake of each horse is described as advantageous. Thus, the farm manager can easily draw conclusions on possible illnesses or technical problems like defective or lost transponders. In case of concentrate feeding stations the farm manager benefits from a reduction of working time and more flexibility concerning daily working practices (Pirkelmann, 1990b, 1998; Kreimeier, 2004; König von Borstel et al., 2010; Zeitler-Feicht et al., 2010).

On the other hand, this feeding technique is associated with relatively high investment costs. These lead to an increased animal/feeding-place ratio of usually 30:1 at concentrate feeding stations. Consequently, a simultaneous feed intake becomes impossible (Kreimeier, 2004; Streit et al., 2008; Zeitler-Feicht et al., 2010). However, Rifá (1990) and Sweeting et al. (1985) have already pointed out the importance of synchronization and social facilitation with respect to the horses' feeding behaviour. Asynchronous feed intake does not comply with the natural behaviour of horses. In case the feeding system does not provide a feeding place for each horse, appropriate measures must ensure at least the simultaneous intake of roughage for all horses (Zeitler-Feicht, 2005; Zeitler-Feicht, 2008; BMELV, 2009). According to the observations of Gülden et al. (2011), the combination of an increased animal/feeding-place ratio at concentrate feeding stations and the natural feeding behaviour of horses inevitably leads to the occurrence of waiting times in front of the feeding stations. Higher animal densities in the waiting area are accompanied by an increased risk of aggressive interactions (Zeitler-Feicht et al., 2011). The occurrence of blocking times caused by horses remaining in the feeding station without concentrate allowance is also described as disadvantageous as these blocking times constrain the feeding process considerably and increase waiting times additionally (Gülden et al., 2011). Furthermore, the dependence on the functional reliability of the applied technology can be noted as a disadvantage for farm managers (Kreimeier, 2004).

Concentrate feeding stations for horses in group housing are available in practice since the beginning of the nineties (Streit, 2009). At the same time, the first scientific studies have been conducted on the use of automatic feeding stations. Already Pirkelmann (1990b) pointed out that the setup of the feeding stall is of vital importance to guarantee an undisturbed feed intake also for low-ranking horses. In particular feeding stalls that cover the whole body length ensure a stress-free environment. The partitions should allow visual contact to other horses at any time. Taking into account ethological aspects, feeding stations that are equipped with a separate entry and exit are more suitable than those that have to be left backwards. One-way stations prevent unnecessary stressful situations especially for low-ranking horses as, while leaving the station, the horses do not have to move backwards against the horses waiting in front of the feeding station. Feeding stations being equipped with a computer-controlled entry barrier guarantee a complete feed intake also for low-ranking horses (Pirkelmann, 1990b, 1990a, 1991). Zeitler-Feicht and Streit (2012) complemented the scientific findings of the early nineties and summarized them in a list of checkpoints for the appropriate feeding of horses at automatic feeding stations. In addition to previous scientific findings, the authors advised enough space for low-ranking horses and the spatial separation of feeding stations for concentrates and hay. The stations' exits should guide the horses to another functional area. It is advised to offer straw ad libitum to guarantee simultaneous feed intake for all horses at any time. The authors recommended a maximum of 10 feeding portions per day at concentrate and hay feeding stations. Furthermore, the horses should be fed at least 1.5 kg hay per 100 kg body weight. Based on the current state of scientific knowledge and taking into account the structural design of concentrate feeding stations, the main aspects ensuring a stress-free and complete feed intake for all horses has been clearly formulated.

In practice, there are great differences concerning the design of entry barriers at automatic feeding stations (Streit, 2009). As they guarantee an undisturbed and stress-free feeding environment for all horses, they are described as an animal-friendly equipment of automatic feeding stations (Zeitler-Feicht et al., 2011). Nevertheless, they cannot exclusively be described as advantageous. Despite the entry barriers' design, their common characteristic is that they increase the occurrence of blocking times caused by horses remaining in the feeding station without concentrate allowance (Pirkelmann, 1990b; Streit, 2009). These blocking times could be observed in different scientific investigations (Pirkelmann, 1990b; Pirkelmann et al., 1993; Streit, 2009; Gülden et al., 2011; Zeitler-Feicht et al., 2011). Gülden et al. (2011) observed average daily blocking times of 14.9 ± 15.9 minutes at a concentrate feeding station in practice. Zeitler-Feicht et al. (2011) even identified average daily blocking times of 36.7 ± 128.4 minutes. Furthermore, they could observe great differences concerning the individual blocking behaviour of the observed horses. Some horses did not block the feeding station at all and others did so for more than two hours. Pirkelmann (1990b) investigated the influence of the horses' social rank on the occurrence of blocking times. He found out that predominantly high-ranking horses are responsible for the emergence of these blocking times. However, recent studies could not verify these findings (Streit, 2009; Gülden et al., 2011).

The reduction of blocking times is of central interest to guarantee an unconstrained feeding process at concentrate feeding stations. Pirkelmann (1990b) observed that blocking times can be reduced by computer-controlled stimulation devices. The use of stimulation devices as negative reinforcers should encourage the horses to leave the feeding station directly after feed intake (Skinner, 1938; Zimbardo and Hoppe-Graff, 1995). Pirkelmann et al. (1993) investigated the efficiency of a live wire rope driving through the feeding station while being connected with a fence energiser. The activation of the rope was indicated by an acoustic signal. In the course of their investigation, Pirkelmann et al. (1993) modified the stimulation device to that extent that the horses left the feeding station with the acoustic signal and without the application of the electric impulse. In recent developments, the stimulation device comprises an acoustic trigger as well as a touch trigger (thin stick). The stimulation device can be controlled individually for each horse. After its activation, the touch trigger passes through the feeding station. The application of an electric impulse is also possible. According to Zeitler-Feicht et al. (2011), the use of stimulation devices applying an electric impulse reduces the blocking times by eleven minutes. Zeitler-Feicht (2005) observed that some horses panic after being subjected to the electric impulse. Consequently, they do not enter the feeding station again voluntarily. Based on these findings, Zeitler-Feicht (2005) concluded that the application of an electric impulse is not compatible with the feeding of horses. Gülden et al. (2011) conducted a telephone survey on the use of stimulation devices at concentrate feeding stations in practice. Taking into account the principles of learning theory, they judged the settings of the stimulation devices undertaken by the farm managers as rarely suitable for a successful conditioning of the horses. Furthermore, many farm managers argued that the application of an electric impulse is the only reliable means to prevent the occurrence of blocking times. On the other hand and based on the current state of knowledge, stimulation devices operating without the application of an electric impulse do not seem to reliably prevent the occurrence of blocking times in the long-term. Gülden et al. (2011) investigated the efficiency of a stimulation device that combined an acoustic signal with the touch of a crop. The crop was lowered onto the horses remaining in the feeding station without concentrate allowance. Although this stimulation device reduced the average daily blocking times significantly from 14.9 ± 15.9 minutes to 0.6 ± 1.3 minutes, the authors could observe a habituation effect after two weeks of application. After four weeks in total, the average daily blocking times had increased to 12.5 ± 17.8 minutes and did not differ significantly from the ones observed without the use of a stimulation device.

According to Zeitler-Feicht et al. (2011), the principle of positive reinforcement is much more suitable to prevent the occurrence of blocking times than an active drive out procedure by means of negative reinforcement. The authors recommend the positioning of the feeding stations exit to provide a view of the roughage feeding area. This measure should motivate the horses to leave the feeding station on their own. Based on the current state of knowledge, a scientific confirmation of this hypothesis is not yet available.

Apart from the described issue of occurring blocking times, the feeding of horses in modern group housing systems remains a topical subject. As only a few scientific studies have been conducted on that topic so far, different authors recommended further “empirical and controlled investigation” (Gülden et al., 2011; Hartmann et al., 2012). The number of feeding times at concentrate feeding stations remains a central issue and is discussed controversially. Meyer and Coenen (2002) found out that horses receiving concentrate feed ad libitum, divided the feed in ten portions daily. The amount of feed did not exceed 0.25 kg/100 kg bodyweight. Therefore, Meyer and Coenen (2002) have recommended full utilisation of all available opportunities to dispense small feeding portions at concentrate feeding stations. According to Pirkelmann et al. (2008), the adequate number of feeding times depends on the horses’ individual feed amount per day. Due to physiological reasons, the maximum feed amount being portioned out per station visit should not exceed 1.5 kg to 2 kg. On the other hand, a lot of small feeding portions cause unnecessary station visits that are disadvantageous regarding utilisation aspects of the feeding station (Pirkelmann et al., 2008). In practice, the objective of high feeding frequencies at concentrate feeding stations is to increase the activity behaviour of horses (Gülden et al., 2011). Frentzen (1994) observed that the transition from four (4 x 1.5 h) to six feeding times (6 x 1 h) increased the activity behaviour of four group housed horses ($p < 0.01$). Hoffmann et al. (2012) investigated the activity behaviour of eight Icelandic horses with ALT- pedometers. ALT is the abbreviation for the variables Activity, Lying time and Temperature. Activity impulses are measured by means of an analogue piezo sensor (Alsaaod et al., 2012). Hoffmann et al. (2012) observed that the implementation of a concentrate feeding station increased the average daily activity of the horses significantly to 23479 ± 5626 impulses (compared to 15957 ± 4001 activity impulses under manual feeding). Rose-Meierhöfer et al. (2010) found out that the stable system has a significant influence on the activity behaviour of the observed horses. According to their findings, higher feeding frequencies at automatic feeding stations might cause the increased activity behaviour in active barns compared with open barns. However, recent studies advise a reduction to ten feeding times per day at concentrate feeding stations (Zeitler-Feicht et al., 2010, 2011; Zeitler-Feicht and Streit, 2012). According to these authors, this approach satisfies the natural feeding behaviour of horses and, at the same time, it might also be suitable to reduce the risk of aggressive interactions in the waiting area.

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2 Scope of the thesis

The current study emerged from the fact that modern horse husbandry clearly benefits from the continuing refinement of automatic feeding stations. The prevention of blocking times at concentrate feeding stations is of central importance to guarantee an unconstrained feeding process. According to the author's opinion, a feeding system will only be completely accepted in practice if it does not raise concerns regarding welfare implications.

The aim of the present thesis was to optimise the feeding process at concentrate feeding stations for horses in group housing. This optimisation primarily focussed on the prevention of blocking times. Therefore, the influence of different positive and negative reinforcers on the horses' blocking behaviour has been investigated in the course of several preliminary tests. The alternative solutions investigated should function efficiently in the long-term and, at the same time, accord with appropriate animal welfare standards.

The first study investigates the suitability of a compressed air stimulus to reduce the occurrence of blocking times in a concentrate feeding station for horses in group housing. Initially, the horses' blocking behaviour was observed without the application of the compressed air stimulus. Afterwards, the horses' behaviour was investigated immediately after the first commissioning of the compressed air stimulus as well as after two and six weeks of compressed air application. This study design guaranteed the verification of short-term and long-term effects. Furthermore, possible influencing factors in the occurrence of blocking times have been investigated and future research focuses are discussed.

The second study investigates a completely different approach to the reduction of blocking times. It was analysed if the occurrence of blocking times is affected by feeding frequencies at concentrate feeding stations. In the first trial period (24-hour feeding regime), the horses' feeding claims were portioned out throughout 24 h. This configuration of the feeding program is characteristic for concentrate feeding stations operated under common conditions in practice. In the second and third trial period, the feeding at the concentrate feeding station was reduced to daytime feeding and, finally, to three feeding times. Furthermore, it was investigated if high feeding frequencies increase the horses' activity behaviour. Focussing on the horses' blocking and activity behaviour, this study design was chosen to give a recommendation regarding an appropriate feeding frequency at concentrate feeding stations.

3 Published trials

3.1 Study 1

The effect of a compressed air stimulus on blocking times in a concentrate feeding station for horses in group housing

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Published in

Applied Animal Behaviour Science 191 (2017) 39-48

The effect of a compressed air stimulus on blocking times in a concentrate feeding station for horses in group housing

Abstract

Concentrate feeding stations are used to meet the different feeding requirements of group-housed horses. In practice, blocking times caused by horses remaining in the feeding station without concentrate allowance constrain the feeding process considerably. To date, the application of an electric shock seems to be the most effective stimulus to prevent these blocking times.

The aim of the present study was to examine the effectiveness of an innovative stimulation device in preventing the occurrence of blocking times. The study was carried out in a so called active barn, a group housing system with a generous space offer which is subdivided into different functional areas (resting, water intake, concentrate intake, roughage intake, paddock, pasture). Each of the 16 horses observed was fed with the help of a concentrate feeding station. As standard, the concentrate feeding station was equipped with a stimulation device that is intended to encourage the horses to leave the station after feed intake. The stimulation device consisted of an acoustic signal (beeper) and a touch trigger (thin stick) that should drive the horses from the feeding station. In the course of the present study, an additional stimulus was implemented, namely the application of compressed air between the horses' hind legs. The behaviour of the horses was recorded with video observation and analysed over a period of 3 × 24 h in each of the trial periods (1. Status quo = no application of compressed air; 2. Compressed air; 3. Compressed air after two weeks of application; 4. Compressed air after six weeks of application).

It was observed that the average daily blocking durations, as well as the average daily blocking frequencies of the horses, could be reduced significantly by the application of compressed air. However, an increase of the observed blocking durations and blocking frequencies during the six weeks of the trial period indicates the occurrence of a habituation effect over time. In the course of the present study it became obvious that there are great individual differences concerning the reaction of the horses to the applied stimulation devices. As the emergence of blocking times is a very complex issue, the authors strongly recommend further scientific research on this topic. Possible future research focuses are discussed in the course of the present study.

Keywords

Horse, Group housing, Feeding station, Blocking times, Stimulation device

Introduction

In practice, different housing systems are available for keeping horses in groups (Gieling et al., 2007). In recent developments, the management of horses in so called active barns has become popular because increasingly more horse owners want to keep their horses under species-appropriate conditions (Hoffmann et al., 2012). The main characteristics of active barns are the spatial separation of the different functional areas for resting, water intake, concentrate and roughage intake as well as a generous space offer (Rose-Meierhöfer et al., 2010). According to the current state of knowledge, this stable design best satisfies the horses' basic needs for locomotion and social contact (Vervuert and Coenen, 2002).

The German Federal Ministry of Food, Agriculture and Consumer Protection recommends the use of feeding stalls to guarantee individual feeding in group housing (BMELV, 2009). In practice, automatic feeding systems are increasingly used to meet the different feeding requirements of group-housed horses (Streit et al., 2008). Responsiveness to a horse's individual needs, as well as the time-controlled feeding process throughout the day, are described as the main advantages of computer-controlled concentrate feeding stations (Pirkelmann, 1990; Kreimeier, 2004). Due to the feeding computer the farm manager can easily check the concentrate intake of each horse. Feed remains might indicate illnesses and technical problems like a defective or lost transponder (Pirkelmann, 1998; Kreimeier, 2004). A reduction of working hours, as well as more flexibility in working practices, can be described as the main advantages of concentrate feeding stations for farm managers (König von Borstel et al., 2010; Zeitler-Feicht et al., 2010).

The main disadvantage of computer-controlled concentrate feeding stations, which could deter uptake, are relatively high investment costs that lead to an increased animal/feeding-place ratio of usually 30:1 (Kreimeier, 2004; Zeitler-Feicht et al., 2010). In contrast to feeding stalls, and as a result of the saving of feeding places, concentrate feeding stations do not allow simultaneous feed intake (Streit et al., 2008). The specific importance of synchronization and social facilitation regarding feed intake has already been pointed out by Rifá (1990) and Sweeting et al. (1985). Due to the natural feeding behaviour of the horses, as well as the increased animal/feeding-place ratio, waiting times in front of concentrate feeding stations are almost inevitable. Blocking times caused by horses remaining in the feeding station without concentrate allowance, constrain the feeding process considerably and increase waiting times additionally (Gülden et al., 2011). According to Zeitler-Feicht et al. (2011) the accumulation of horses in the waiting area (in front of the feeding station) leads to an increased risk of aggressive interactions. Although Gülden et al. (2011) observed that the two lowest ranking horses had to wait for more than two hours throughout several observation days to obtain their feeding claims, a statistically significant difference concerning waiting times between low-ranking and high-ranking horses has not yet been verified (Gieling et al., 2007; Streit, 2009; Gülden et al., 2011).

The setup of the feeding stall is of vital importance to guarantee an undisturbed feed intake at automatic feeding stations for all horses. Already Pirkelmann (1990) pointed out that the feeding stall should cover the whole body length to ensure a stress-free environment and complete feed intake also for low-ranking horses. Nevertheless, the partitions should allow visual contact to the other horses. Concerning ethological aspects, one-way stations with a separate entry and exit are more suitable than stations that have to be left backwards (Pirkelmann, 1990; Zeitler-Feicht et al., 2011). Based on the current state of knowledge, feeding stations that are equipped with an entry barrier are classified as animal-friendly because they guarantee an undisturbed feed intake for all horses (Pirkelmann, 1990; Zeitler-Feicht et al., 2011). Although there are great differences concerning the design of the entry barriers in practice, their common characteristic is that they increase the occurrence of blocking times caused by horses standing inside the station without concentrate allowance (Pirkelmann, 1990; Streit, 2009). The average daily blocking durations of the horses observed in different scientific investigations range from 14.9 ± 15.9 min (Gülden et al., 2011) to 36.7 ± 128.4 min (Zeitler- Feicht et al., 2011). Zeitler-Feicht et al. (2011) could identify great individual differences − some horses did not block the feeding station at all, however, others did so for more than two hours. In contrast to Pirkelmann (1990), recent studies could not identify a statistically significant influence of the horses' social rank on the occurrence of blocking times (Streit, 2009; Gülden et al., 2011).

According to Pirkelmann (1990) blocking times can be reduced by a computer-controlled stimulation device that is activated if necessary. In general, these stimulation devices are used as negative reinforcers. Zimbardo and Hoppe-Graff (1995) describe a negative reinforcer as a stimulus that increases the occurrence of a specific reaction to the presented stimulus in case the stimulus is taken from the situation. Pirkelmann et al. (1993) investigated a stimulation device that drove through the feeding station. An acoustic signal indicated the activation of a live wire rope being connected with a fence energiser. After appropriate modifications the horses left the feeding station with the activation of the acoustic signal and without getting in contact with the electric shock. Gülden et al. (2011) observed that the application of a stimulation device was able to reduce the average daily blocking durations of the horses significantly from 14.9 ± 15.9 min to 0.6 ± 1.3 min. The stimulation device consisted of an acoustic signal (beeper) and the touch of a crop. The crop was lowered onto the horses standing in the feeding station and operated without the use of an electric shock. The stimulation device complied with the principles of classical conditioning. The acoustic signal sounded for five seconds while the feeding trough was closed. Then the crop was activated and the acoustic signal sounded for a further five seconds. Gülden et al. (2011) observed a habituation effect already after two weeks of application. The heart rate measurements conducted verified their observations. Zeitler-Feicht et al. (2011) pointed out that blocking durations were eleven minutes shorter in the case of feeding stations equipped with a stimulation device that applied an electric shock. In recent developments, the stimulation device comprises an acoustic signal as well as a touch trigger (thin stick) that passes through the feeding station and can be activated, including an electric shock, if necessary. However, the use of an electric shock as a stimulation device is controversial and cannot be applied without restrictions (Streit, 2009; Gülden et al., 2011). Zeitler-Feicht (2005) found out that some horses panic after the application of the electric shock and are not motivated to enter the feeding station again. According to Zeitler-Feicht (2005), the use of an electric shock is incompatible with the feeding of horses and cannot be described as compliant to appropriate animal welfare standards (Zeitler-Feicht et al., 2011). The fact that the use of an electric shock is the only means to efficiently prevent the occurrence of blocking times points out the high discrepancy between scientific theory and what is done in practice (Gülden et al., 2011). This fact confirms the conclusion of Hartmann et al. (2012) who stated that "innovative housing designs" for group-housed horses and especially the implemented feeding regimes should be further investigated because only a few scientific studies have been conducted to date.

The current study emerged from the authors' opinion that a feeding system will only be completely accepted in practice if it accords with appropriate animal welfare standards. The aim of the present study was to evaluate the effectiveness of a compressed air stimulus in preventing the occurrence of blocking times. Due to the encouraging results of different preliminary studies on the manual application of compressed air, we conducted the present test series. We expected that the compressed air stimulus would be appropriate to prevent the occurrence of blocking times in concentrate feeding stations. As the horses responded reliably to the compressed air stimulus in the preliminary studies, we expected that a habituation effect would not occur over time.

Materials and methods

Housing system

The study was conducted at a horse farm in the west of Germany between July and September 2014. The group housing system investigated was designed for 30 horses and covered a total area of 3500 m^2 (Fig. 1). The housing system was divided into different functional areas (resting area, concentrate feeding station, roughage area, water intake, paddock, pasture). The central stable (300 m^2) comprised an engineering room, two resting areas (262.5 m^2) and three boxes to enable the gradual integration of new horses. The resting areas were bedded with forest soil and had two different entries and exits. A concentrate feeding station (Schauer Agrotronic GmbH) was placed at the gable end of the central stable to supply the horses with concentrate and mineral supplements throughout the day. A rack offering straw ad libitum was placed in the paddock. Additionally, three hay racks were placed in a separate roughage area (750 m^2). The access times to the roughage area were controlled individually for each horse by an automatic sorting station. The horses could leave the roughage area through two gates leading back to the paddock. In order to prevent fodder losses, all racks were covered with hay nets. Four frost-proof drinkers as well as mineral licks were available in the paddock. The housing system comprised a grazing area of 30,000 m^2, which was divided into two lots. The access times to the pasture were controlled individually for each horse by an automatic selection gate.

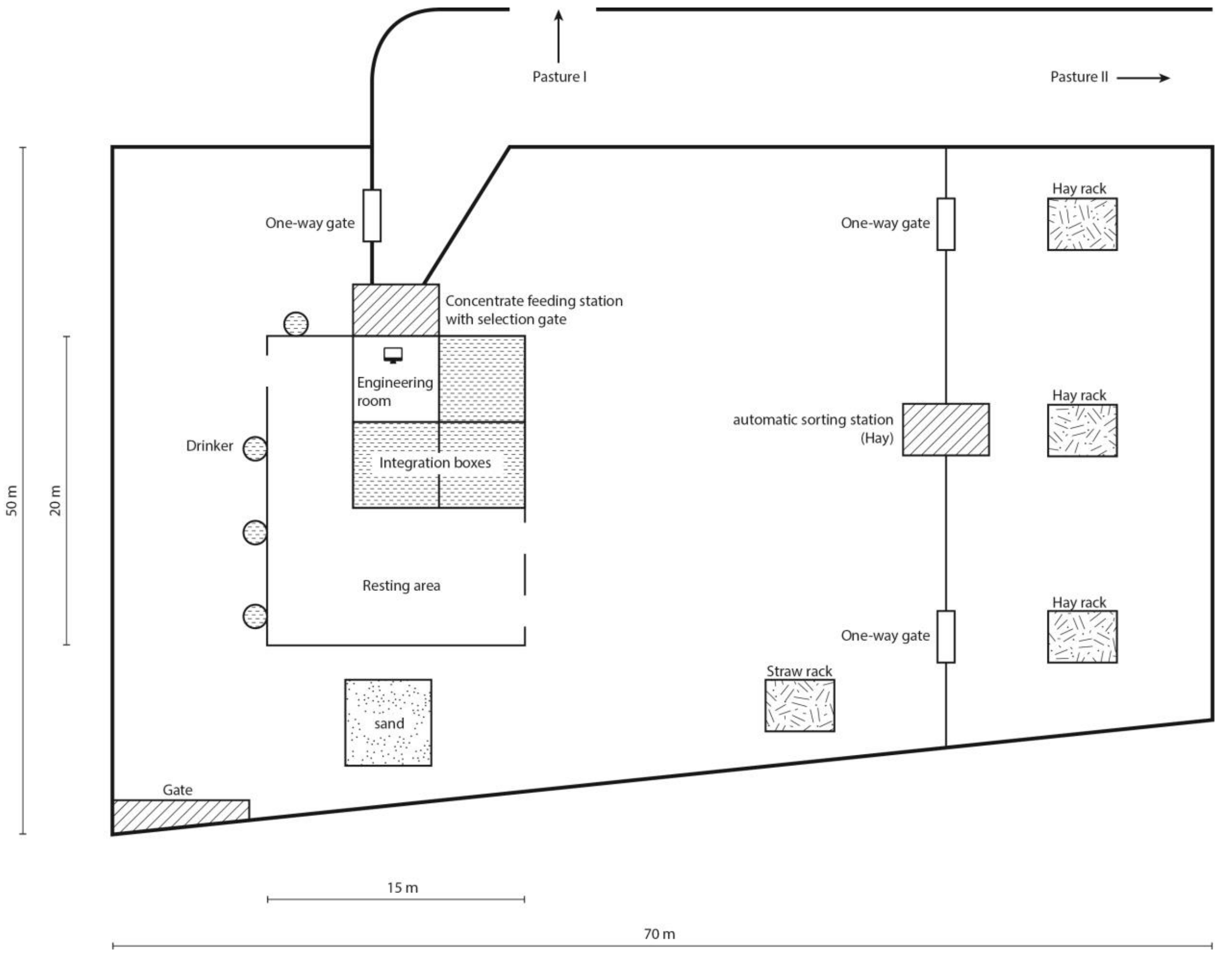

Fig. 1. The investigated active barn.

Concentrate feeding station and feeding process

An automatic feeding station was used to supply the horses with concentrates and mineral supplements throughout the day (Fig. 2). The feeding station was designed as a one-way station and equipped with an entry barrier. The entry barrier consisted of two pneumatically controlled black wing doors (rubber mats) that closed the feeding station when it was occupied. The pneumatically controlled feeding trough was installed at the head of the first corridor and only accessible for the horses in the case of a legitimate feeding claim. The second corridor of the concentrate feeding station was attached at a right angle to the first corridor. The exit gate was installed at the end of the second corridor and could only be opened from inside the feeding station. It consisted of two small wing doors that had to be pushed open by the horses when leaving the station. As standard, the concentrate feeding station was equipped with a stimulation device that is intended to encourage the horses to leave the station after feed intake. The stimulation device consisted of an acoustic signal (beeper) and a touch trigger. The touch trigger can be described as a thin stick. After its activation, it should drive the horses from the feeding station by touching the horses' hindquarters. In practice, the touch trigger can be used in combination with an electric shock in order to force the horses to leave the feeding station. At the beginning of the present study, the horses were used to the sound of the acoustic signal and the touch of the thin stick. At no time before or during the investigation were the horses forced to leave the station through the application of an electric shock.

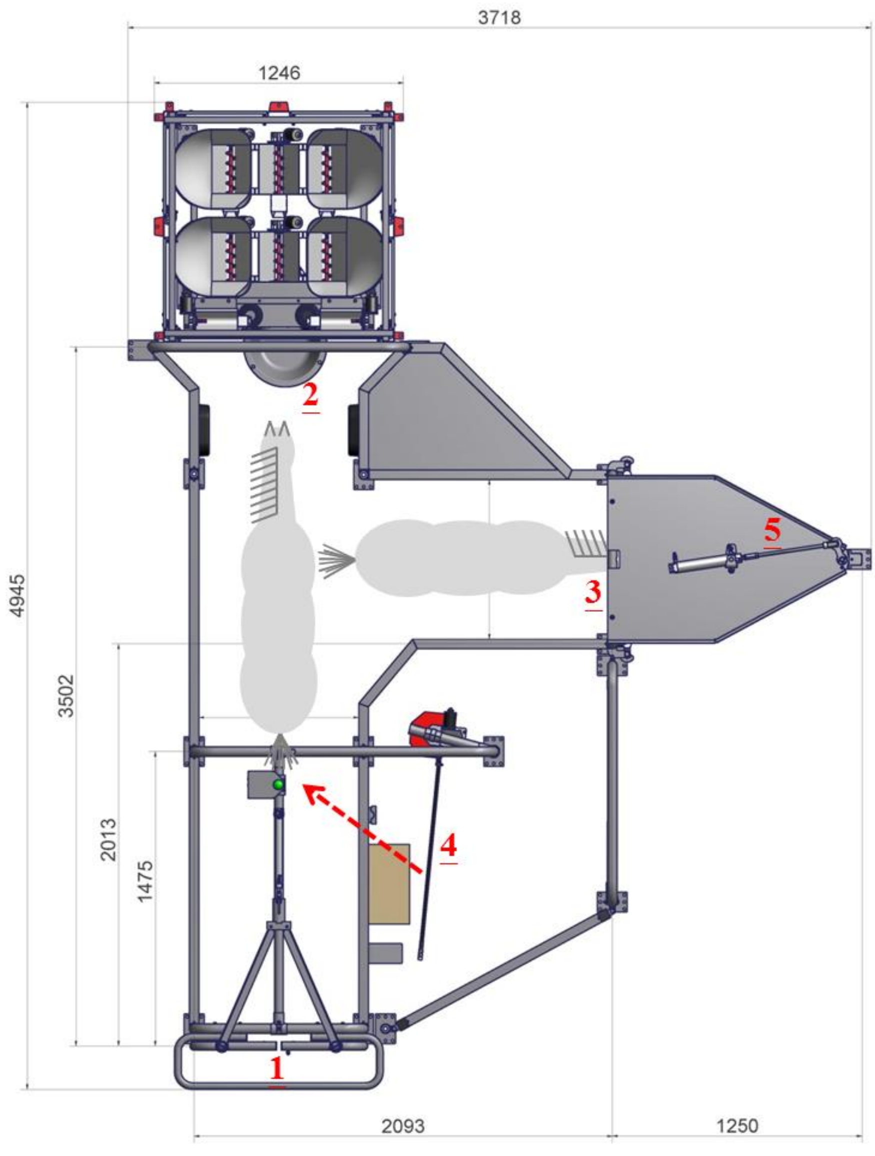

Fig. 2. The investigated concentrate feeding station (1 = entry barrier; 2 = trough; 3 = exit gate; 4 = touch trigger and its application; 5 = selection gate; dimension specifications in mm) (modified from Schauer Agrotronic GmbH).

A photoelectric sensor (SUNX EQ500) installed in the feeding station registered the entrance of a horse and triggered the closing of the entry barrier. Once in the feeding station, the horses were identified by means of RFID-Technology. The low-frequency 32 mm glass transponder (Texas Instruments Incorporated; RI-TRP-RE2B) was attached to the horses' right or left front leg by means of a ribbon. A soft pad beneath the ribbon was used to prevent pressure marks on the horses' legs. The horses have been used to the transponder ribbon since their use during the first commissioning of the concentrate feeding station. The antenna (0.8 m^2) was installed right in front of the feeding trough. Furthermore, an inductive sensor provided information about the presence of a horse in the feeding station. Once the horse has left the feeding station through the exit gate, this was registered by the feeding computer with the means of an inductive sensor fixed at the exit gate. The concentrate feeding station was equipped with a selection gate. It was installed directly after the exit gate, and controlled the access to pasture or paddock individually for each horse. The horses were not able to re-enter the feeding station immediately after each visit. Irrespective of whether the horses were led to the paddock or the pasture after feed intake, they had to walk around the central stable in order to return to the feeding station again.

The concentrate rations consisted of oat, pellets, cereal and mineral feed, which had been prepared individually for each horse. The feeding claims were not provided all at once, but in separate portions throughout the whole day. The amount of feed being portioned per visit in the concentrate feeding station differed. It depended on the individual horse's total amount of feed per day as well as the horse's number of station visits. The different ingredients were always portioned out in the following proportions: 26 g of oat; 48 g of pellets; 29 g of cereals; 9 g of mineral feed. Remaining feeding portions were dispensed after 7 pm. At midnight, the feeding portions and feeding allowances for the next day were calculated and left-over feeding portions were deleted.

The entry barrier closed directly after the horse had entered the concentrate feeding station. After the identification of the horse the feeding computer checked the feeding allowance of the horse. In the case of a legitimate feeding claim, the trough swung out and the feed was portioned out at intervals. If there was also an existing pasture claim, the selection gate swung to the correct position. During the adjustable residence time after the last feeding portion was provided, the horses had time to empty the trough before it swung away and was no longer accessible. Activation of the stimulation devices started with the removal of the trough. The horses had to take a step back from the trough before entering the second corridor. The entry barrier opened after the horse had left the station, entering either the paddock or pasture as appropriate.

Experimental design

The manual application of a compressed air stimulus at the flank as well as between the hind legs of the horses delivered encouraging results in two preliminary tests. Therefore, the test series was divided into four trial periods:

1. Status quo
2. Compressed air stimulus
3. Compressed air stimulus after two weeks of application
4. Compressed air stimulus after six weeks of application

The horses had been used to the settings of the feeding parameters in the Status quo for 12 weeks. The portioning interval lasted 15 s. After the last feeding portion the horses were allowed a residence time of eighty-five seconds to empty the trough. As the trough swung away, the acoustic signal sounded for five seconds. The touch trigger was not activated. Fig. 3 shows the feeding process during the trial period Status quo over time.

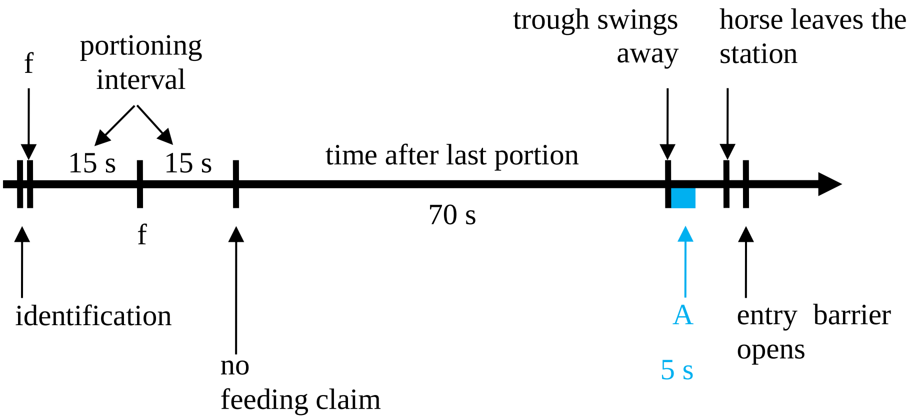

Fig. 3. The feeding process during the trial period Status quo (f = feeding portion; A = acoustic signal).

In the second part of the test series it was investigated whether the application of compressed air between the hind legs of the horses is an adequate stimulation device to reduce the occurrence of blocking times caused by horses without concentrate allowance. For this purpose, a thin tube was fixed to the touch trigger (1035 mm above the ground), and the application of compressed air (pressure of 6 bar; ALUP EKV 400 A) was incorporated as part of the central feeding program. The feeding parameters were identical to the settings for the Status quo trial. As for the Status quo, the end of the feeding process was signalled by the swinging of the trough and the sound of the acoustic signal. The touch trigger and the compressed air were activated five seconds after the activation of the acoustic signal. After ten seconds in total the acoustic signal stopped. The touch trigger as well as the compressed air were active for five more seconds. After these five seconds the compressed air stopped as well and the touch trigger stayed active until the horse had left the feeding station. We assumed that the chosen stimulus cascade would be suitable to condition the horses successfully to leave the feeding station. After trial period 2 the duration of the acoustic signal had to be adjusted to 10 s. Fig. 4 shows the feeding process during the trial periods 2–4 over time.

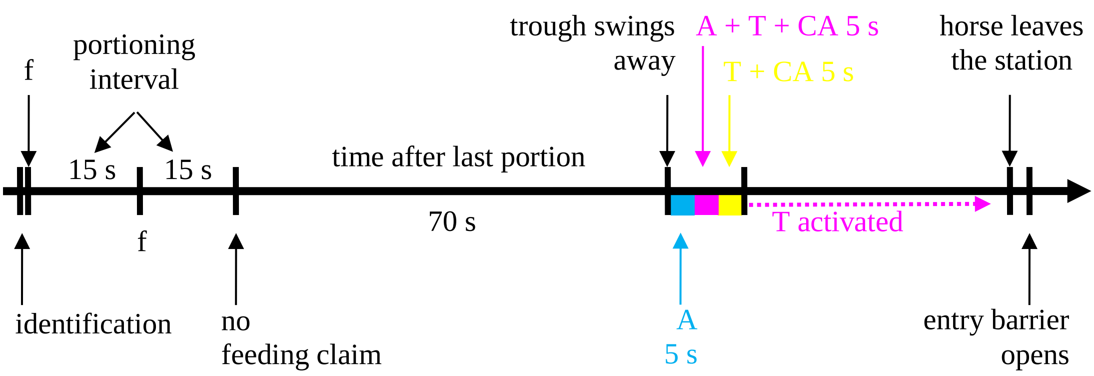

Fig. 4. The feeding process during the trial periods 2 - 4 (f = feeding portion; A = acoustic signal; T = touch trigger; CA = Compressed air).

Animals and daily routines

The horses were kept in a mixed group concerning sex, age and breed. The number of horses kept in the group housing system ranged from 26 to 30 horses during the trial period. The investigation was carried out with 16 privately-owned horses (11 geldings, 5mares). These horses were kept for leisure purposes and had been introduced to the housing system more than six months before data collection began. On average, the horses were introduced to the group housing barn 2.1 ± 0.6 years prior to the study. The average age of the 16 horses was 16.3 ± 5.9 years and ranged from 6 up to 22 years.

During the whole study the concentrate feeding station was operating 24 h a day. In the Status quo test period the horses received between 150 g and 3000 g of concentrate every day (on average 1035.6 g ± 840.7 g). As the feeding claim of one horse was adapted in the second part of the test series, there were marginal differences according to the average feeding claims of the horses (trial period 2: 1023.1 g ± 845.9 g; trial period 3 and 4: 1015.0 g ± 865.0 g). The pasture access was open from 9 am until 6 pm and controlled by an automatic selection gate installed in the concentrate feeding station. Four of the 16 horses observed were allowed a reduced grazing period of 3 h, 6 h (2 horses) and 7 h. An automatic sorting station controlled the access to the roughage area individually for each horse and operated 24 h a day. 12 of the 16 horses observed had access to the roughage area throughout 3 × 2 h. The remaining four horses had access over 24 h a day. The horses could leave the roughage area at any time through two one-way gates leading back to the paddock. The cleaning of the group housing system took place between 9 am and noon.

Behaviour analyses

The horses' behaviour was recorded by three video cameras (SEC-CAM750) that were installed in the concentrate feeding station before the beginning of the present study. The observation time was 24 h over three successive days in each trial period. The individual marking of the sixteen horses was not necessary as each horse was identified correctly by the RFID-Technology of the concentrate feeding station. Every stay in the concentrate feeding station of the horses was evaluated. Recording the 'length of each stay', the 'feeding time' and the ‘blocking time’ was of particular importance. Blocking times occurred in two different situations:

1. The horse entered the feeding station without a feeding claim and did not leave the station despite the activation of the stimulation devices.
2. The horse had a feeding claim when entering the station, ate the apportioned feed but did not leave the station as a result of the stimulation devices.

In both cases the recording of the ‘blocking times’ started when the stimulation devices stopped and ended when the horse left the concentrate feeding station.

Statistical analyses

The recorded data were transferred to Microsoft Excel 2010 and subsequently imported to IBM SPSS Statistics 22. SPSS for Windows was used for the statistical analysis of the ‘visit duration’, the ‘feeding times’, the ‘blocking times’ as well as the corresponding frequencies in the different trial periods. The data were checked concerning the normal distribution using the Kolmogorov-Smirnov-Test. The normality test showed that the recorded data were not normally distributed. Therefore, the Friedman-Test was used to determine statistically significant differences in the observed behavioural parameters between the four trial periods. In case the Friedman-Test delivered a significant result, the Wilcoxon-Test with Bonferroni correction was used to point out the specific significant differences between the trial periods. The level of significance was set to $p < 0.05$. The blocking behaviour of the observed horses will be presented by means of Boxplots (Box-Whisker-Plot) showing the median, the upper and lower quartile as well as outliers (‘o’) and extreme values (‘*’).

In order to investigate possible influencing factors, the horses were grouped according to sex, age (≤ 10 years; 11–19 years; ≥ 20 years), total amount of concentrate feed (≤ 500 g; 501 g–1000 g; 1001 g–1500 g; > 1500 g), pasture time (9 h; less than 9 h) and roughage feeding time (24 h; less than 24 h). The Mann-Whitney-U-Test was used to determine the influence of sex as well as pasture and roughage feeding time on the average daily blocking times of the horses. In case of age and total amount of concentrate feed, the Kruskal-Wallis-Test was used to point out significant differences.

Results

The effect of a compressed air stimulus on the use of the feeding station and the feed intake

Table 1 shows that the activation of compressed air as a stimulation device led to an increased visit frequency in the concentrate feeding station. Nevertheless, a statistically significant difference between the four trial periods could not be verified. Table 1 points out that, in the first instance, the activation of the compressed air decreased the visit duration in the concentrate feeding station by one third compared to the Status quo. But after six weeks of application, the visit duration was comparable to that of the Status quo again. As for the visit frequencies, a statistically significant difference between the four trial periods could not be proven for the visit duration.

Table 1. Average 'visit frequencies' [visits $horse^{-1}$ d^{-1}] and average 'visit durations' [min $horse^{-1}$ d^{-1}] of the observed 16 horses in the concentrate feeding station during the different trial periods (s.d. = standard deviation).

trial period	visit frequency			visit duration		
	Mean ± s.d.	Min.	Max.	Mean ± s.d.	Min.	Max.
Status quo	7.5 ± 3.4	2.7	13.3	31.6 ± 25.8	4.0	113.1
Compressed air	9.2 ± 6.0	2.0	22.7	19.9 ± 14.5	3.9	54.2
Compressed air (2 weeks)	8.2 ± 4.3	2.0	15.3	26.9 ± 24.1	2.8	96.6
Compressed air (6 weeks)	9.5 ± 5.4	2.7	21.0	30.8 ± 26.3	3.2	89.6

The average daily 'feeding frequencies' of the observed 16 horses ranged from 6.1 ± 3.0 to 6.9 ± 3.9 in the four trial periods. The corresponding average feeding durations ranged from 14.8 ± 9.1 to 15.6 ± 1.5 min per day. These results show that the 'feeding frequency' as well as the 'feeding duration' differed only marginally throughout the test series. The statistical analyses confirmed that the activation of the compressed air had no significant influence on the average feeding frequencies and the average feeding durations of the horses.

The effect of a compressed air stimulus on blocking frequencies and blocking times

The average daily 'blocking frequency' of the horses differed significantly between the four trial periods ($p < 0.001$). In the Status quo the average daily 'blocking frequency' of the horses was 6.2 ± 3.3. Due to the activation of the compressed air the blocking frequency could be reduced significantly ($p = 0.001$) to 0.8 ± 1.9. After two weeks of compressed air application (blocking frequency: 3.4 ± 4.6) as well as after six weeks (blocking frequency: 4.7 ± 5.5) the concentrate feeding station was blocked less than in the Status quo, but that difference was no longer statistically significant (Fig. 5).

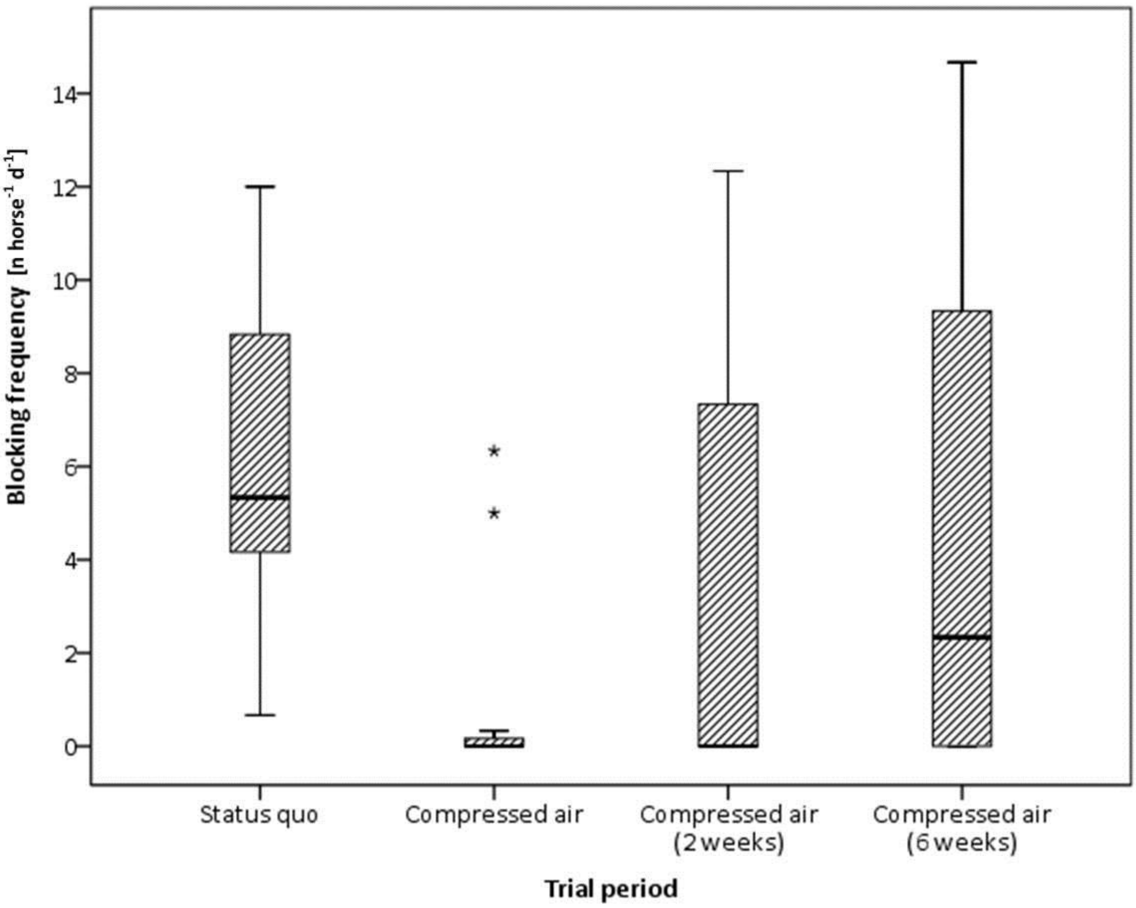

Fig. 5. The daily 'blocking frequencies' [n $horse^{-1}$ d^{-1}] of the observed 16 horses in the concentrate feeding station in the four trial periods.

As for the average 'blocking frequencies', the average daily 'blocking durations' of the observed 16 horses in the concentrate feeding station also differed significantly between the four trial periods ($p = 0.001$). Due to the activation of the compressed air, the average daily 'blocking durations' of the horses could be reduced from 15.9 ± 19.2 min (Status quo) to 3.2 ± 11.3 min. This reduction was statistically significant ($p = 0.006$; level of significance after Bonferroni correction at $p < 0.0083$). The average daily 'blocking durations' of the horses after two weeks of compressed air application (9.8 ± 16.0 min) as well as after six weeks of compressed air application (11.4 ± 14.8 min) were still shorter than in the Status quo, but this difference was also no longer statistically significant (Fig. 6).

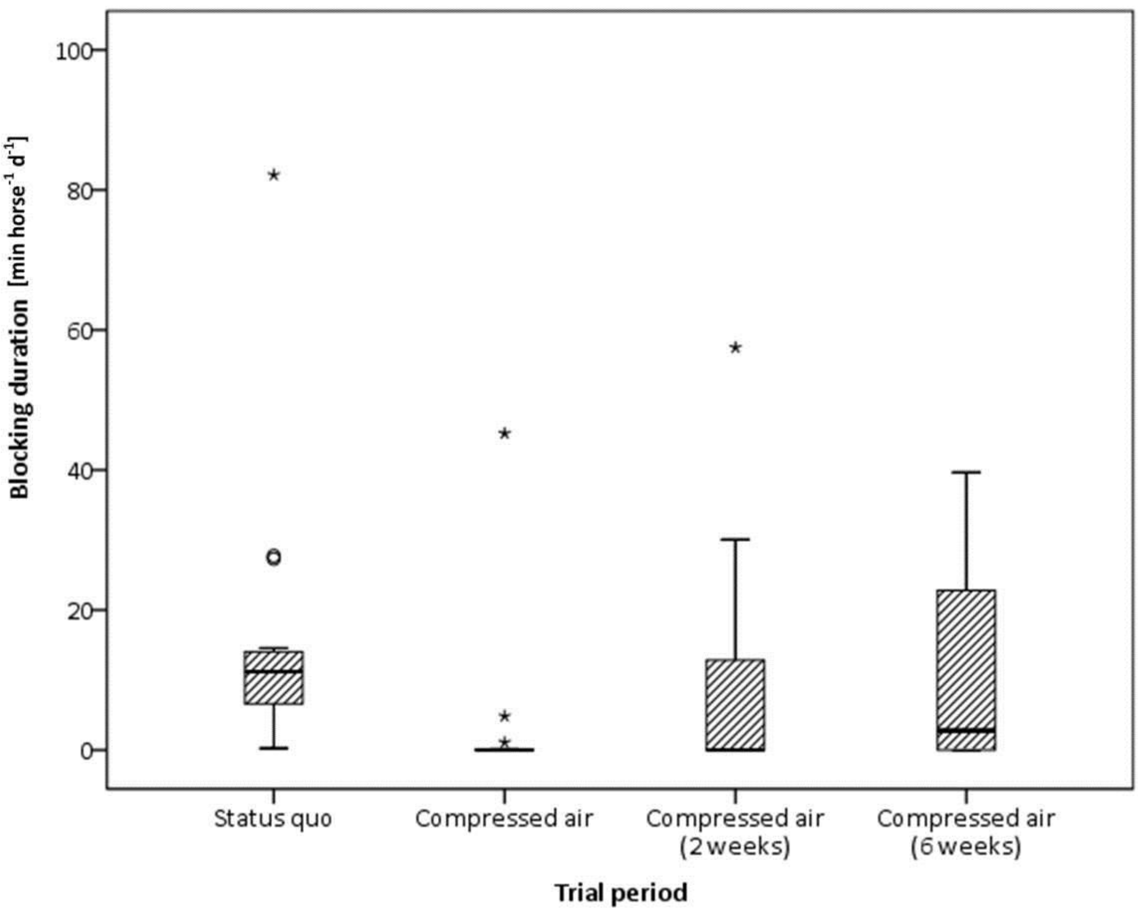

Fig. 6. The daily 'blocking durations' [min $horse^{-1}$ day^{-1}] of the observed horses in the concentrate feeding station in the four trial periods.

In the Status quo 84% of the station visits were accompanied by blocking times. Due to the activation of the compressed air, this proportion could be decreased to 8%. In the second part of the test series this proportion increased to 42% (Compressed air after 2 weeks) and finally to 51% (Compressed air after 6 weeks). Taking a look at the signals that finally made the horses leave the station shows that in each of the Compressed air trial periods the horses left the feeding station mainly with the acoustic signal. On the basis of all station visits this proportion was relatively constant with 34% (Compressed air), 33% (Compressed air after two weeks) and 31% (Compressed air after six weeks). After the compressed air activation the horses left the feeding station in 30% of the observed station visits with the combined stimulation device of acoustic signal and compressed air stimulus. This proportion decreased to 10% (Compressed air after two weeks) and finally to 7% (Compressed air after six weeks).

The analysis of the individual horses showed that in the Status quo all the observed horses consistently blocked the concentrate feeding station. The average daily blocking durations of the horses ranged from 0.2 ± 0.2 to 82.2 ± 71.7 min. The horse with the lowest average daily blocking duration only blocked the feeding station on two of the three observation days. The horse with the highest average daily blocking duration blocked the feeding station for 161.6 min in the course of one observation day. Due to the activation of the compressed air the proportion of horses causing blocking times could be reduced to four individuals. The average daily blocking durations of these four horses ranged from 0.1 ± 0.3 to 45.2 ± 33.9 min. These four horses did not respond to the compressed air reliably right from the beginning of its activation. In the long-term, the number of horses causing blocking times in the concentrate feeding station increased to seven and finally to ten individuals over the application period.

The statistical analysis has shown that neither the pasture and roughage feeding time nor the total amount of concentrate feed had a significant influence on the average daily blocking times of the horses. Furthermore, the blocking behaviour was not influenced by the sex of the observed horses.

Throughout the whole study the young horses blocked the concentrate feeding station longer than the old and the middle aged horses. In the Status quo as well as the trial period Compressed air this difference was not statistically significant. In the trial period Compressed air after two weeks the young horses blocked the feeding station with 18.0 ± 10.8 min significantly longer ($p = 0.033$) than the middle aged horses with 1.3 ± 3.4 min. The same observation was made after six weeks of compressed air application (26.4 ± 10.4 min versus 0.1 ± 2.1 min; $p = 0.028$). In both trial periods a statistically significant difference could not be proven for the old horses.

Discussion

The present study has shown that the use of the tested stimulation device influences the blocking behaviour of horses in concentrate feeding stations. The average daily blocking durations could be reduced significantly from 15.9 ± 19.2 min in the Status quo to 3.2 ± 11.3 min in the trial period Compressed air. Gülden et al. (2011) tested a stimulation device that consisted of an acoustic signal in combination with the touch of a crop. The crop was lowered on the horses standing in the feeding station. Gülden et al. (2011) also observed a decrease in the average daily blocking durations with the activation of the stimulation device (from 14.9 ± 15.9 min to 0.6 ± 1.3 min). Zeitler-Feicht et al. (2011) found out that the blocking durations were 11 min shorter in the case of stimulation devices operated with an electric shock. Thus, the main results of different authors could be verified in the course of the present study (Pirkelmann, 1990; Gülden et al., 2011; Zeitler-Feicht et al., 2011).

The blocking durations of the observed horses increased during the present study. After two weeks of compressed air application, the horses blocked the feeding station on average for 9.8 ± 16.0 min a day. The average daily blocking durations increased further to 11.4 ± 14.8 min after six weeks of compressed air application. Gülden et al. (2011) also observed increased blocking durations in the course of their study (7.4 ± 21.2 min after two weeks; 12.5 ± 17.8 min after four weeks). These results lead to the conclusion that the use of the described stimulation devices reduces the occurrence of blocking times in the short-term, but not reliably in the long-term.

The increasing proportion of station visits being accompanied by blocking times as well as the extent of the emerging blocking times clearly indicate a habituation effect. Habituation is defined as “waning of responsiveness” to repeated stimulation (Rankin et al., 2009; Manning and Dawkins, 2012). Described as a simple form of learning, habituation leads to a frequency decrease and/or magnitude decrease of the response to the stimulus. Furthermore, habituation is "relatively long-lasting" and "stimulus-specific" (Rankin et al., 2009; Manning and Dawkins, 2012). As Gülden et al. (2011) also observed a habituation effect during the application period of the stimulation device, these results can be confirmed with the present study. Nevertheless, the observed habituation effect was only applicable to six of the observed 16 horses.

Corresponding with the referenced literature (Gülden et al., 2011; Zeitler-Feicht et al., 2011), the present study revealed great individual differences regarding the blocking behaviour of the observed horses. While one horse did not block the feeding station at all throughout one observation day, another one did so for 161.6 min. As the concentrate feeding station controlled access to the pasture, it might have been possible that horses with more limited pasture access time blocked the feeding station. Additionally, the total amount of concentrate feed might have been an influencing factor in the occurrence of blocking times. Horses with small feeding claims might not leave the feeding station as they expect further feed to be provided. But neither the pasture time nor the amount of feed had a significant influence on the emerging behaviour of the horses with respect to blocking time. The influence of the individual roughage feeding time has also been considered. It might have been possible that horses with a reduced roughage feeding time visit the concentrate feeding station more often throughout the observation day. But this theory could not be verified in the course of the present study.

Taking a look at the sex and age of the horses as possible influencing factors revealed that after two and six weeks of compressed air application the young horses (≤ 10 years) blocked the feeding station significantly longer than the middle aged horses (11–19 years). In the case of the old horses (≥ 20 years) no significant influence could be verified. All of the observed horses were integrated into the active barn more than six months before the data collection started. Therefore, the integration date can be dropped as a possible explanation for differences in blocking behaviour.

In the present study negative reinforcement was used to prevent the occurrence of blocking times. According to Skinner (1938), "a reinforcing stimulus is defined as such by its power to produce the resulting change". Four horses did not respond to the compressed air stimulus reliably right from the beginning. This fact demonstrates that the applied stimulus can be classified as non-reinforcing for these horses (Skinner, 1938). For the remaining 12 horses the compressed air stimulus had a reinforcing character. As described above, six horses became inured to this innovative stimulation device and blocked the feeding station again. But for the remaining six horses the compressed air application led to the desired behaviour even after six weeks. These results clearly indicate that the perception of the applied stimuli differed enormously between the individual horses. Zeitler-Feicht (2005) also identified great differences concerning the reaction of the horses to the stimulation device. She observed that the use of an electric shock triggered a panic reaction in some of the horses. The fact that these horses did not enter the feeding station again inevitably raises concerns regarding welfare implications. Zeitler-Feicht (2005) and Zeitler-Feicht et al. (2011) describe the approach of applying an electric shock to force the horses to leave the feeding station as incompatible with animal welfare from the scientific point of view. On the other hand, this procedure seems to be the only means to prevent the occurrence of blocking times reliably in practice (Gülden et al., 2011). The results of the present study have shown that the application of compressed air might be a suitable alternative stimulation device for a reasonable proportion of horses. Although the compressed air application was not effective for all horses, the major advantage of this stimulation device is its compatibility with animal welfare considerations. It was observed that all horses entered the feeding station again, after the first application of compressed air, in their usual manner. Each horse repeatedly entered the feeding station on the first observation day of the trial period Compressed air. This fact shows that any negative effects on welfare relating to the application of a compressed air stimulus are negligible.

In the present study the reinforcing stimulus was presented with an acoustic signal. The acoustic signal started five seconds before the application of compressed air and remained active in parallel with the compressed air stimulus for a further five seconds. This temporal overlap should help to turn the neutral stimulus into a conditioned reinforcer (Zimbardo and Hoppe-Graff, 1995). The results of the present study have shown that the horses predominantly left the feeding station with the beginning of the acoustic signal. The proportion of station visits that were accompanied by a direct contact with the compressed air decreased from 30% (Compressed air) to 10% and then to 7% (Compressed air after six weeks). This development clearly shows that the neutral stimulus has turned into a conditioned reinforcer as described by Zimbardo and Hoppe-Graff (1995). Consequently, the use of an acoustic signal is suitable to indicate the next step of the drive out procedure. In case of higher stimulation intensity this approach would be advantageous with regard to welfare considerations.

The temporal succession of the acoustic signal and the following stimuli is an important prerequisite for a successful learning process. Gülden et al. (2011) conducted a telephone survey on the setting of stimulation devices at concentrate feeding stations in practice. They interviewed farm managers and discovered that the successful conditioning of horses is rarely achieved due to the settings of the stimulation devices used by farm managers. Improved practice in the use of stimulation devices may therefore be accomplished through the production of “off-the-shelf” solutions by industries, which apply the principles of learning theory. Consequently, the farm managers would only have to decide for which horses the stimulation device should be activated.

In practice, one can find different opinions regarding the handling of unnecessary blocking times in concentrate feeding stations. Besides the active drive out procedure through negative reinforcement, Zeitler-Feicht et al. (2011) suggest the use of positive reinforcement to motivate the horses to leave the feeding station. In their opinion, the positioning of the feeding stations exit to provide a view of the roughage feeding area might be a suitable solution. In a preliminary test on positive reinforcement we tested the effect on the horses’ behaviour of offering water and a food reward directly behind the feeding station. The results of these preliminary tests lead to the conclusion that full implementation of these measures should not be undertaken without detailed consideration of the disadvantages arising. Based on our collected data, we cannot give a clear recommendation on this topic.

Taking a look at a comparable situation in livestock farming and the legal bases might be conductive at that point. In dairy farming the milking process can be automatized by using milking robots. Unnecessary blocking times are caused by cows staying in the milking robot after the milking process. In order to achieve the maximum capacity of automatic milking systems (AMS), some of them are equipped with a stimulation device applying an electric shock. This approach forces the cows to leave the automatic milking system as quickly as possible. Consequently, the access to the milking robot can be opened earlier for the next cow (Wechsler et al., 2012). In Switzerland the equipment of automatic milking systems with stimulation devices applying an electric shock is forbidden (BLV, 2005; Wechsler et al., 2012). In Germany, the Animal Protection Law (TierSchG, 2006) regulates the protection of animals in principle. Section 2, § 3 number 11 prohibits the use of devices applying an electric shock to force animals to move or to restrict their movement in case the animal experiences not insignificant pain, suffering or injuries. Due to the formulation "not insignificant pain, suffering or injuries", the Animal Protection Law allows interpretation at that point. Critics as well as supporters of stimulation devices applying an electric shock argue on the basis of their own conviction. Critics claim that the application of an electric shock leads to a stressful situation (Zeitler-Feicht, 2005; Streit, 2009; Gülden et al., 2011; Zeitler-Feicht et al., 2011). At the same time, this procedure is not uncommon in practice to operate the automatic feeding stations without restrictions (Gülden et al., 2011). According to learning theory, positive reinforcement is more suitable to evoke a new reaction or stabilize an already existing one than negative reinforcement (Zimbardo and Hoppe-Graff, 1995). Due to the facts described above, further scientific research is needed and strongly recommended. To go beyond speculation at this point, the importance of negative as well as positive reinforcement should be considered in the prevention of blocking times. Any alternative solution should be practicable and compliant to appropriate animal welfare standards.

As Hartmann et al. (2012) have already pointed out, there have only been a few scientific studies concerning the feeding regimes in modern group housing systems for horses. According to the results of the present study and the referenced literature, the use of concentrate feeding stations for horses in group housing has decisive advantages for horses, horse owners and farm managers. In practice, active barns differ enormously concerning design, particularly with regard to space offer and general conception, as well as professional management. However, as Zeitler-Feicht et al. (2011) have already pointed out, these factors are of vital importance for a successful group housing system.

On the subject of feeding management at concentrate feeding stations, there are two main areas for further research: the number of daily feeding portions which depends on the total amount of feed and the animal/feeding-place ratio. Both factors directly influence the occupancy of the feeding station. Consequently, these factors indirectly influence the occurrence of waiting times in front of the station (Gülden et al., 2011; Zeitler-Feicht et al., 2011). In the present study the average daily feeding frequency did not differ significantly in the conducted test series. It only ranged from 6.1 ± 3.0 to 6.9 ± 3.9 between the four trial periods. This fact indicates that the horses do not really exploit the opportunity to pick up their feeding claims every hour throughout the whole day. This result confirms the recommendation of Zeitler-Feicht et al. (2011) to reduce the feeding portions to a maximum of ten per day. From a nutritional point of view, it seems to be unnecessary to assign daily feeding claims of 1000 g in ten portions throughout the day. In practice, the objective of a high feeding frequency is to increase the activity behaviour of the horses. Pirkelmann et al. (2008) point out that due to physiological reasons the assigned feeding portion should not exceed 1.5–2 kg concentrates per station visit. At the same time the authors argue that lots of small portions lead to unnecessary station visits and a high occupancy of the feeding station. We have collected our own data concerning the influence of the feeding frequency on the activity behaviour of horses and the occurrence of blocking times in concentrate feeding stations. This data is currently being prepared for publication. Taking a look at the animal/feeding-place ratio clearly shows that the impact of occurring blocking times increases with the number of horses being fed by one feeding station. A recommendation for the animal/feeding-place ratio at automatic feeding or sorting stations, based on scientific studies, does not yet exist. This issue should be the focus of further research.

General structural aspects of the feeding stations would also benefit from further scientific investigations. It should be investigated if the combination of feeding and selecting in one concentrate feeding station makes sense from an ethological point of view because, as a consequence, blocking times affect the fluctuation within several functional areas of the group housing system. The fact that the horses have to leave the feeding station at a right angle should also be scrutinized in case the applied stimulation device triggers a flight reaction. At the same time it should be ensured that the horses are not able to avoid the stimulation device without leaving the feeding station.

An evaluation of the limitations of the present study also leads to specific recommendations for further scientific research. The experimental setup was only tested on one group of horses at one barn. Additionally, the given sample size of 16 horses can be described as relatively small. Although the tested barn represents a typical active barn operated under common conditions in practice, the authors suggest further investigations to test and verify the results at active barns with different conceptual designs. Furthermore, it is not possible to separate the effects of compressed air from the combined effect of the touch trigger plus compressed air. Preliminary studies showed that the application of compressed air was most efficient when it was applied between the horses' hind legs. Due to constructional reasons, this could only be implemented by fixing the compressed air tube to the touch trigger. For an off-the-shelf solution the implementation of the compressed air stimulus to the drive out procedure possibly needs to be modified.

Conclusions

The investigated concentrate feeding station was operated under common practice conditions. All of the observed horses consistently blocked the feeding station in the Status quo. This resulted in a constrained feeding process and led to fluctuation restrictions within the housing system. The investigated compressed air stimulus was suitable for one third of the observed horses. These 6 horses did not block the feeding station reliably in the short-term as well as in the long-term. However, it could be observed that the horses' responses to the applied stimuli differ enormously. Therefore, the implementation of an acoustic signal and a stimulus cascade seems to be appropriate to prevent the occurrence of blocking times.

The present study demonstrates that the emergence of blocking times is a very complex issue, with large variations in the behaviour of horses observed. We therefore recommend the interdisciplinary teamwork of ethologists, professionals in animal nutrition and development engineers in order to gain further scientific insights. Future research projects should focus on the feeding management, the suitability of potential positive or negative reinforcers and the constructional design of concentrate feeding stations. Animal welfare considerations should form the basis for any scientific research approach.

Acknowledgements

This research was financially supported by the Mehl-Mülhens-Foundation and conducted in cooperation with Schauer Agrotronic GmbH. The authors would like to thank the farm manager as well as the involved horse owners for supporting the investigation.

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3.2 Study 2

The effect of different feeding regimes on horses' blocking and activity behavior at a concentrate feeding station for horses in group housing

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Published in

Journal of Veterinary Behavior 24 (2018) 27-35

Abstract

Automatic feeding stations are increasingly used to feed group-housed horses. In practice, horses without a feed allowance often cause blocking times in concentrate feeding stations. The consequences are a constrained feeding process and increased waiting times in front of the feeding station. Stimulation devices are used to prevent these blocking times, if necessary, by applying an electric impulse.

The aim of the study was to examine if the feeding regime implemented at a concentrate feeding station influences the blocking behavior of horses. Furthermore, the influence of the applied feeding frequency on the activity behavior of the horses was investigated.

The study was carried out in an active barn with different functional areas. A concentrate feeding station was used to supply each of the 19 horses observed with concentrate and mineral supplements throughout the day. The horses' behavior in the concentrate feeding station was recorded with video observation. The observation time was 3 x 24 hours in each trial period: (1) 24-hour feeding, (2) daytime feeding (feeding between 6 am and midnight), (3) three feeding times. Additionally, the activity behavior of 9 horses was recorded by means of ALT pedometers (activity, lying time, and temperature) throughout the observation days.

The daytime feeding regime did not reduce the average daily blocking frequency and the average daily blocking duration of the horses. Only the implementation of 3 feeding times significantly reduced the blocking frequency ($P = 0.001$) as well as the blocking duration ($P = 0.013$). The reduction in feeding times led to a significant increase in the horses' activity. Although the activity of the horses was highest with the application of 3 feeding times (13009.9 ± 2682.8 activity impulses), a significant difference was found for the 24-hour feeding regime ($P < 0.001$) but not for the daytime feeding regime ($P = 0.107$).

The reduction of feeding times can be described as advantageous with respect to blocking behavior and the activity behavior of the observed horses. Nevertheless, this reduction did not reliably prevent the occurrence of blocking times. The authors recommend further interdisciplinary research on the use of concentrate feeding stations. A holistic approach taking into account structural, nutritional, and ethological aspects is advisable.

Keywords

horse, group housing, feeding station, blocking time, pedometer; activity

Introduction

The management of horses in so-called active barns has become more and more popular in modern horse husbandry. This housing system is characterized by a generous space offer and the spatial separation of the different functional areas (BMELV, 2009; Eurich-Menden, 2006; Hartmann et al., 2012; Hoffmann et al., 2012; Rose-Meierhöfer et al., 2010). Besides feeding stalls, automatic feeding systems are increasingly used to supply the horses with concentrates throughout the day. The advantages and disadvantages associated with this feeding technique are described in the relevant literature (Gülden et al., 2011; König von Borstel et al., 2010; Kreimeier, 2004; Pirkelmann, 1990, 1998; Streit et al., 2008; Zeitler-Feicht et al., 2010, 2011).

The occurrence of blocking times in the feeding station caused by horses without concentrate allowances can be observed in practice. The occurrence and duration of blocking has been reported in multiple studies. The average daily blocking times range from 14.9 ± 15.9 minutes (Gülden et al., 2011) and 15.9 ± 19.2 minutes (Gülden and Büscher, 2017) to 36.7 ± 128.4 minutes (Zeitler-Feicht et al., 2011). In contrast to Pirkelmann (1990), recent studies did not verify that blocking times are predominantly caused by high-ranking horses (Gülden et al., 2011; Streit, 2009). So far, neither the individual roughage feeding time and amount of concentrates nor the individual access time to pasture could be identified as possible influencing factors on the occurrence of blocking times (Gülden and Büscher, 2017).

In practice, stimulation devices that are said to follow the principle of negative reinforcement (Skinner, 1938) are used to reduce blocking times in concentrate feeding stations. Many farm managers view the application of an electric impulse as the only reliable means to prevent these blocking times (Gülden et al., 2011; Pirkelmann et al., 1993; Zeitler-Feicht et al., 2011). From a scientific point of view, this approach is described as incompatible with appropriate animal welfare standards (Zeitler-Feicht, 2005; Zeitler-Feicht et al., 2011). Section 2, § 3 number 11 of the German Animal Protection Law prohibits the application of an electric shock to force or restrict animals' movement in case the animal experiences "not insignificant pain, suffering, or injuries." This formulation does not ensure an unambiguous legal situation and allows interpretation for critics as well as supporters of stimulation devices (Gülden and Büscher, 2017; TierSchG, 2006). Stimulation devices operating without the application of an electric impulse do not seem to reliably reduce the occurrence of blocking times in the long-term (Gülden and Büscher, 2017; Gülden et al., 2011).

To date, only a few scientific studies have been conducted on the feeding of horses in modern group housing systems (Gülden and Büscher, 2017; Gülden et al., 2011; Hartmann et al., 2012). The feeding frequency at concentrate feeding stations remains a central and somewhat controversial issue. High-feeding frequencies are recommended from a nutritional point of view and to increase the activity behavior of horses (Frentzen, 1994; Hoffmann et al., 2012; Meyer and Coenen, 2002; Rose-Meierhöfer et al., 2010). However, recent studies advise a reduction to 10 feeding times per day to reduce the risk of aggressive interactions in the waiting area (Zeitler-Feicht and Streit, 2012; Zeitler-Feicht et al., 2010, 2011).

The aim of the present study was to investigate a completely new approach to the reduction of blocking times. We studied whether the feeding frequency influences the horses ' blocking and activity behavior. We hypothesized that a higher feeding frequency at a concentrate feeding station would not, in fact, increase the activity behavior of the observed horses.

Materials and methods

A detailed description of the housing system and the concentrate feeding station investigated has already been provided in Gülden and Büscher (2017) and will be summarized briefly in the present study to enable better understanding.

Housing system and animals

The study was conducted at a horse farm in the west of Germany between January and May 2014. Thirty horses were housed in the investigated group housing system. The spatial separation of functional areas was the main characteristic for this active barn covering a total area of 3500 m^2 (Figure 1). Throughout the day, the horses had permanent access to the resting area bedded with forest soil (262.5 m^2), the concentrate feeding station (Schauer Agrotronic GmbH, Prambachkirchen, Austria), and the paddock (2450 m^2; fortified with limestone grit). A rack offering straw ad libitum, 4 frost-proof drinkers, mineral licks, and a sandy wallowing place were available in the paddock. Additionally, the housing system was equipped with a separate roughage area (750 m^2) including 3 hay racks covered with hay nets. The access to this area was controlled individually by an automatic sorting device and the use of radio-frequency identification (RFID). The sorting directions (roughage area and paddock) are indicated in Figure 1. The 2 exits from the roughage area were designed as one-way gates leading back to the paddock.

The concentrate feeding station was equipped with an entry barrier (2 pneumatically controlled wing doors of rubber mats) and an exit gate (2 small wing doors). A separate entry and exit ensured that the horses did not have to step back while leaving the station. The feeding trough was pneumatically controlled and only accessible in the case of an existing feeding claim. A selection gate was installed behind the exit gate and this controlled access to the pasture individually for each horse. The sorting directions (paddock and pasture) are indicated in Figure 1.

RFID technology was used in the sorting device and the concentrate feeding station. Therefore, an antenna (0.8 m^2) was installed in both devices and the RFID transponders (RI-TRP-RE2B; Texas Instruments Incorporated, Dallas, USA) were attached to one of the horses' front legs by means of a padded plastic ribbon. The concentrate feeding station was equipped with a stimulation device to prevent the occurrence of blocking times. This stimulation device consisted of an acoustic trigger (beeper) and touch trigger (thin stick) that can be used in combination with an electric impulse at the discretion of the farm manager. At the beginning of the present study, the horses were used to the acoustic and touch trigger. At no time before or during the investigation was the electric impulse activated.

The concentrate feeding station supplied the horses with individual rations of concentrates (oats, pellets, and cereals) and mineral feed throughout the day. The ingredients for each ration were portioned out in small proportions (oats: 26 g; pellets: 48 g; cereals: 29 g; mineral feed: 9 g) and at portioning intervals of 15 seconds. The horses were granted a residence time (85 s) to empty the trough after the last feeding portion is made available. After the expiration of this residence time, the trough swung away and was no longer accessible. The swinging of the trough was accompanied by the acoustic signal (5 s). The touch trigger was not activated. Except for 4 horses, the entry barrier did not open until the horse had left the feeding station.

Furthermore, the horses had access to a grazing area of 30,000 m^2 (2 plots) via an automatic selection gate installed in the concentrate feeding station. The grazing management (continuous grazing in winter; strip grazing in periods with grass growth; daily assignment by the farm manager) was adapted in the last trial period to guarantee the same pasture conditions throughout the whole study.

The group of horses observed was heterogeneous concerning sex, age, and breed. The investigation was carried out with 19 privately owned horses (13 geldings and 6 mares). These horses were kept for leisure purposes and had been introduced to the housing system more than 5 months before data collection began. On average, the horses were introduced to the group housing barn 1.7 ± 0.8 years before the study. The average age of the 19 horses was 15.1 ± 5.7 years and ranged from 6 up to 24 years.

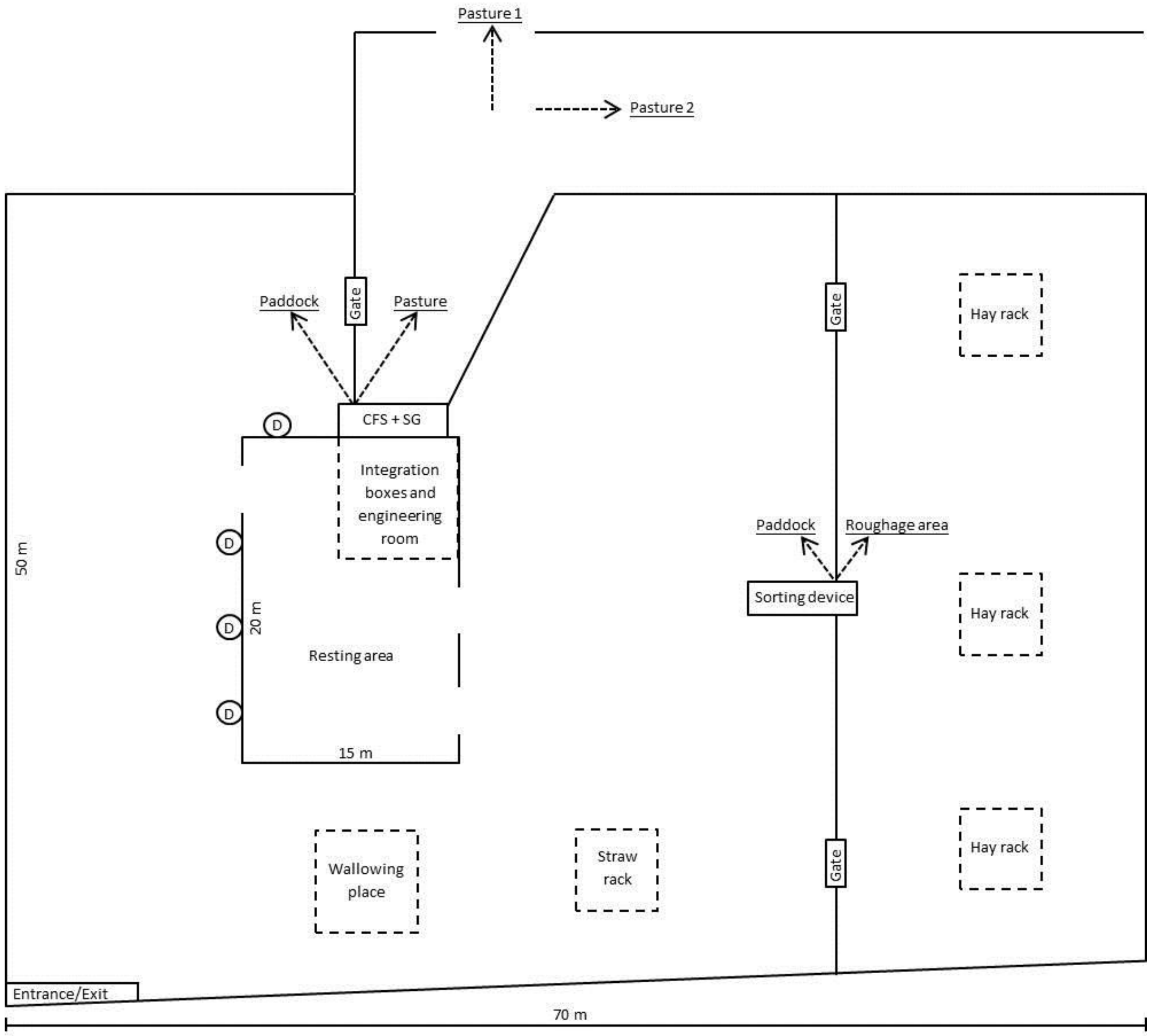

Fig. 1. The functional elements of the investigated active barn (CFS + SG, concentrate feeding station + selection gate; D, drinker).

Experimental design

The test series was divided into 3 trial periods. These trial periods differed concerning the applied feeding regime at the concentrate feeding station:

1. 24-hour feeding regime,
2. daytime feeding regime,
3. three feeding times.

In the first trial period (24-hour feeding regime), the feeding claims were portioned out throughout 24 hours. The feeding portions and feeding allowances for the next day were calculated at midnight, and any remaining feeding portions were deleted. Between midnight and 7 pm, the concentrate feeding station portioned out 5% of the individual feeding rations every hour, provided that the feeding claim could be apportioned given the minimum size of the different ingredients and the individual horses present. Remaining feeding portions were dispensed after 7 pm. The observed horses received between 0 g (2 horses) and 1000 g concentrate plus mineral supplementation every day (on average, 472.6 ± 328.4 g feed). The pasture access was opened at 9 am. The horses were familiar with this feeding regime since the first commissioning of the concentrate feeding station.

In the second trial period (daytime feeding regime), the feeding at the concentrate feeding station was reduced to the time between 6 am and midnight. As for the 24-hour feeding regime, the feeding station portioned out the feed in hourly intervals (8% of the feed ration) taking into account the minimum size of the different ingredients mentioned previously. As the feeding claim of 2 horses changed, the horses received, on average, 430.0 ± 302.1 g feed per day (ranging from 0 to 1000 g concentrate plus mineral supplementation). Feeding portions that had not been picked up throughout the day were dispensed after 7 pm. As for the 24-hour feeding regime, the access to pasture was opened at 9 am. Between 9 am and 10 am as well as between midnight and 6 am, the feeding station was accessible, but no concentrate was dispensed. The horses were allowed an acclimatization period of 4 weeks in which the feed rations as well as the access times to pasture and roughage area were not changed.

In the third trial period, the feeding frequency was further reduced to 3 feeding times. One-third of the individual feeding claim was dispensed between 6 am and 9 am. The second feeding period lasted from 1 pm to 4 pm. Analogous to the previous trial periods, the last feeding time started at 7 pm and ended at midnight. As the feeding claim of 1 horse was modified, the horses received, on average, 432.6 g ± 300.7 g feed per day (ranging from 0 g to 1000 g concentrate plus mineral supplementation). During the remaining hours, the feeding station was accessible, but no feed was portioned out. The horses were granted the same acclimatization time as in the second trial period.

Behaviour analyses

The horses' behavior was recorded by means of 3 video cameras (SEC-CAM750; König Electronic GmbH, Reichelsheim, Germany). The observation time was 24 hours over 3 days in each trial period (Monday, Wednesday, and Friday of the same week). During the observation days, the horses stayed in the housing system for 24 hours. If necessary, separation of the horses for a few minutes was possible between 10 am and noon and between 7 pm and 9 pm.

Every visit to the concentrate feeding station by the horses was registered. The evaluation of the observed "visit duration," "feeding duration" and "blocking duration," as well as the corresponding frequencies, was of crucial importance. The "feeding duration" was defined as the period of time the feeding trough was accessible for the horses. Irrespective of an existing feeding claim, blocking times were recorded if the horses did not leave the concentrate feeding station when the stimulation device was activated. The recording of each "blocking duration" started when the acoustic trigger stopped and ended when the horse left the concentrate feeding station.

Furthermore, the activity behavior of 9 horses was recorded by means of ALT pedometers (Ingenieurbüro Holz, Falkenhagen, Germany). ALT is the abbreviation for the variables activity, lying time, and temperature (Alsaaod et al., 2012). These pedometers measure activity impulses by means of an analog piezo sensor. During the observation time of 24 hours over 3 days in each trial period, the ALT pedometer was attached at the left hind leg with means of a strap with Velcro fastener. A soft pad (fleece filled with polyurethane foam; Pferdesporthaus Loesdau GmbH & Co. KG, Bisingen, Germany) was used to prevent pressure marks at the horses' legs. In order to familiarize the horses with the ALT pedometers, they were attached on the day before data collection started. The horses were equipped with the ALT pedometers throughout the whole trial period, but, if necessary to avoid pressure marks, these were moved to the right hind leg. The horses were assigned the same pedometers throughout the whole study.

The measuring interval of the ALT pedometers was set to 5 minutes. Thus, 288 data sets were generated throughout 24 hours. The number of activity impulses and the lying time were automatically summed up at the end of the measuring interval and saved in a data set together with the ambient temperature and the time stamp. During the days between the observation days, the pedometer readings were transferred to a computer by means of radio transmission. The data sets were stored in a Microsoft Access 2010 (Microsoft Corporation, Redmond, USA) database for further processing. Lying time as well as the ambient temperatures were measured but not further regarded in the course of the present study.

Statistical analyses

The recorded behavioral data ("visit duration," "feeding duration," "blocking duration," and the corresponding frequencies) were transferred to Microsoft Excel 2010 (Microsoft Corporation, Redmond, USA) and subsequently imported to IBM SPSS Statistics 22 (IBM, Armonk, USA) for further statistical analysis. The Kolmogorov-Smirnov test showed that the recorded behavioral data were not normally distributed. Therefore, the Friedman test was used to determine statistically significant differences in the observed behavioral parameters between the 3 trial periods. In case the Friedman test delivered a significant result, the Wilcoxon test with Bonferroni correction was used to point out the specific significant differences between the trial periods. The level of significance was set to $P < 0.05$.

According to the Kolmogorov-Smirnov test, the recorded activity data were normally distributed. Thus, a one-factor analysis of variance with repeated measurements and Bonferroni correction was used to point out the significant differences between the 3 trial periods. The level of significance was set to $P < 0.05$.

The average daily "visit duration," "feeding duration," "blocking duration," and the corresponding frequencies as well as the average daily activity impulses of the horses are presented as mean ± standard deviation in the course of the present study.

Results

The influence of different feeding regimes on the use of the concentrate feeding station

In the 24-hour feeding regime, the horses visited the concentrate feeding station, on average, 7.8 ± 4.1 times throughout the day. With the introduction of the daytime feeding regime, the average daily "visit frequency" of the horses decreased to 7.3 ± 3.4. Finally, the average number of station visits was lowest with the application of 3 feeding times (6.3 ± 3.1). However, none of these differences were statistically significant ($P = 0.071$).

In contrast to the observed "visit frequency" in the concentrate feeding station, the average daily "visit duration" of the horses differed significantly between the 3 trial periods ($P < 0.001$). In the 24-hour feeding regime, the horses visited the concentrate feeding station on average 28.7 ± 16.4 minutes per day. The implementation of the daytime feeding regime decreased the average daily "visit duration" in the concentrate feeding station significantly to 20.1 ± 14.1 minutes ($P = 0.008$). Due to the introduction of 3 feeding times, the average daily "visit duration" of the horses could be further reduced to 12.7 ± 9.7 minutes. This was significantly lower than in the 24-hour feeding regime ($P < 0.001$) and the daytime feeding regime ($P = 0.002$).

The influence of different feeding regimes on feed intake

The average daily "feeding frequency" of the 19 horses observed differed significantly between the 3 trial periods ($P < 0.001$). In the 24-hour feeding regime, the average daily "feeding frequency" of the horses was 5.5 ± 3.4. The implementation of the daytime feeding regime decreased the average daily "feeding frequency" significantly to 3.7 ± 2.2 ($P = 0.002$). With the introduction of 3 feeding times in the last trial period, the average daily "feeding frequency" of the horses decreased further to 1.8 ± 1.2 and was significantly lower ($P < 0.001$) than in the other 2 trial periods.

The average daily "feeding duration" also decreased significantly with the reduction of the feeding times ($P < 0.001$). In the 24-hour feeding regime, the horses spent on average 9.9 ± 6.3 minutes per day in the concentrate feeding station for feed intake. With the transition to the daytime feeding regime, the average daily "feeding duration" was reduced significantly to 7.3 ± 4.8 minutes ($P = 0.003$). With the implementation of 3 feeding times, the average daily "feeding duration" of the horses amounted to 4.9 ± 4.0 minutes and was significantly lower than in the 24-hour feeding regime ($P < 0.001$) and in the daytime feeding regime ($P < 0.001$).

Examining the pattern of feeding portions that were not picked up by the horses in the 3 trial periods explains the decrease in the observed "feeding frequency" and "feeding duration." The amount of feed not being portioned out increased with the reduction of feeding times in the course of the present study (24-hour feeding regime: 589.3 g ± 342.9 g; daytime feeding regime: 801.3 g ± 466.7 g; 3 feeding times: 1304.3 g ± 192.1 g). The analysis of the individual horses showed that in each trial period, 8 horses (daytime feeding regime: 9 horses) did not pick up their overall feeding claim during at least 1 day of each trial period. Five of these horses had feed remains in every trial period.

The influence of different feeding regimes on the blocking behavior of the horses

The average daily "blocking frequency" of the horses differed significantly between the 3 trial periods ($P = 0.001$). In the 24-hour feeding regime, the average daily "blocking frequency" was 6.9 ± 3.8 per horse. With the implementation of the daytime feeding regime, the average daily "blocking frequency" could be slightly reduced to 6.1 ± 3.5 ($P = 0.155$). Through the application of 3 feeding times, the "blocking frequency" could be further reduced to 5.0 ± 2.9 and was significantly lower ($P = 0.001$) than in the 24-hour feeding regime and in the daytime feeding regime (Figure 2).

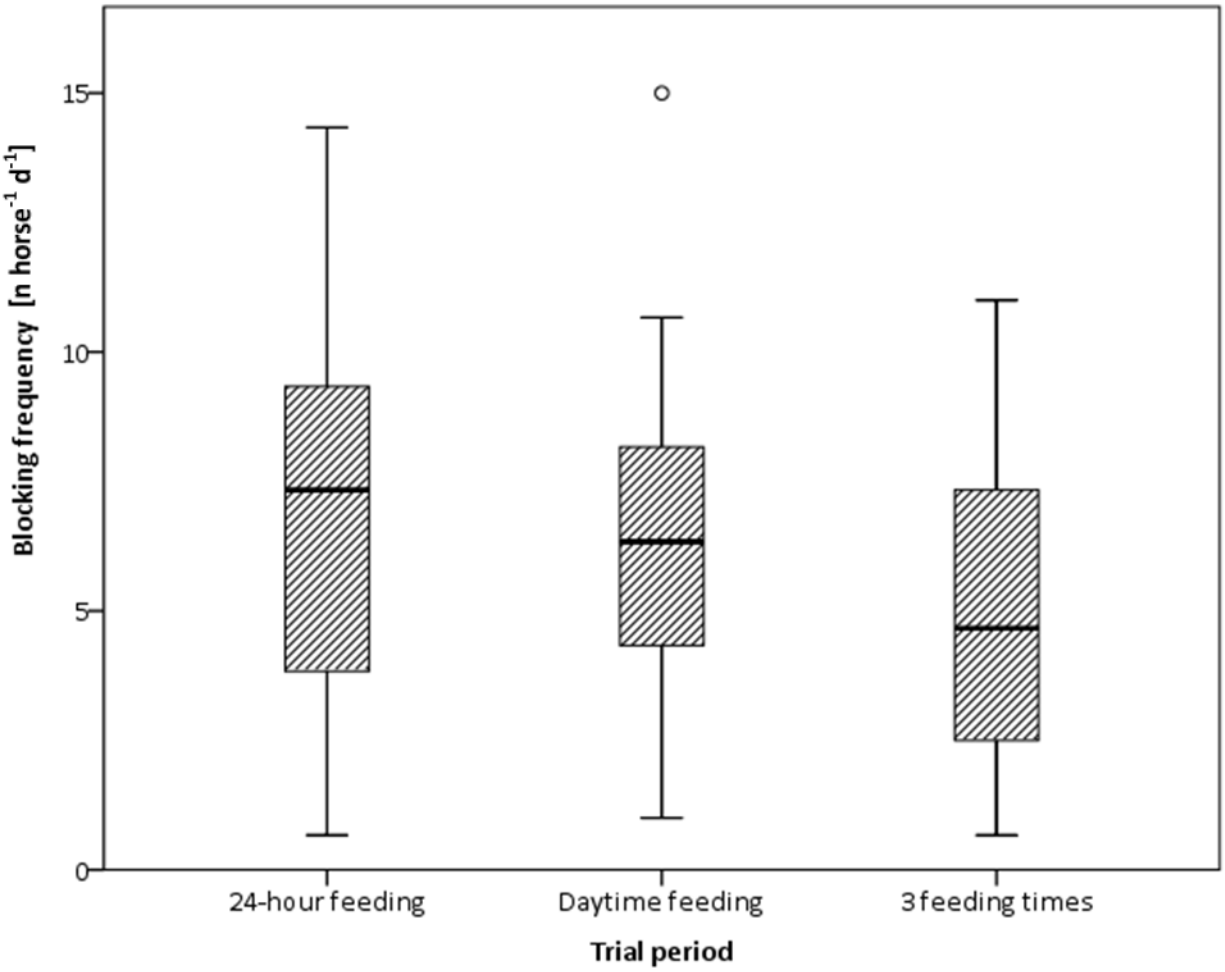

Fig. 2. The daily 'blocking frequency' [n horse^{-1} d^{-1}] of the observed 19 horses in the concentrate feeding station during the 3 trial periods. ° represents outliers.

The average daily "blocking duration" of the horses also differed significantly between the 3 trial periods ($P = 0.003$). The implementation of the daytime feeding regime reduced the average daily "blocking duration" from 17.6 ± 14.2 minutes (24-hour feeding regime) to 11.9 ± 12.1 minutes per horse. However, this reduction was not significant. With the transition to 3 feeding times throughout the day, the average daily "blocking duration" of the horses was 7.6 ± 7.2 minutes, which was significantly lower than in the 24-hour feeding regime ($P = 0.002$) and in the daytime feeding regime ($P = 0.013$) (Figure 3).

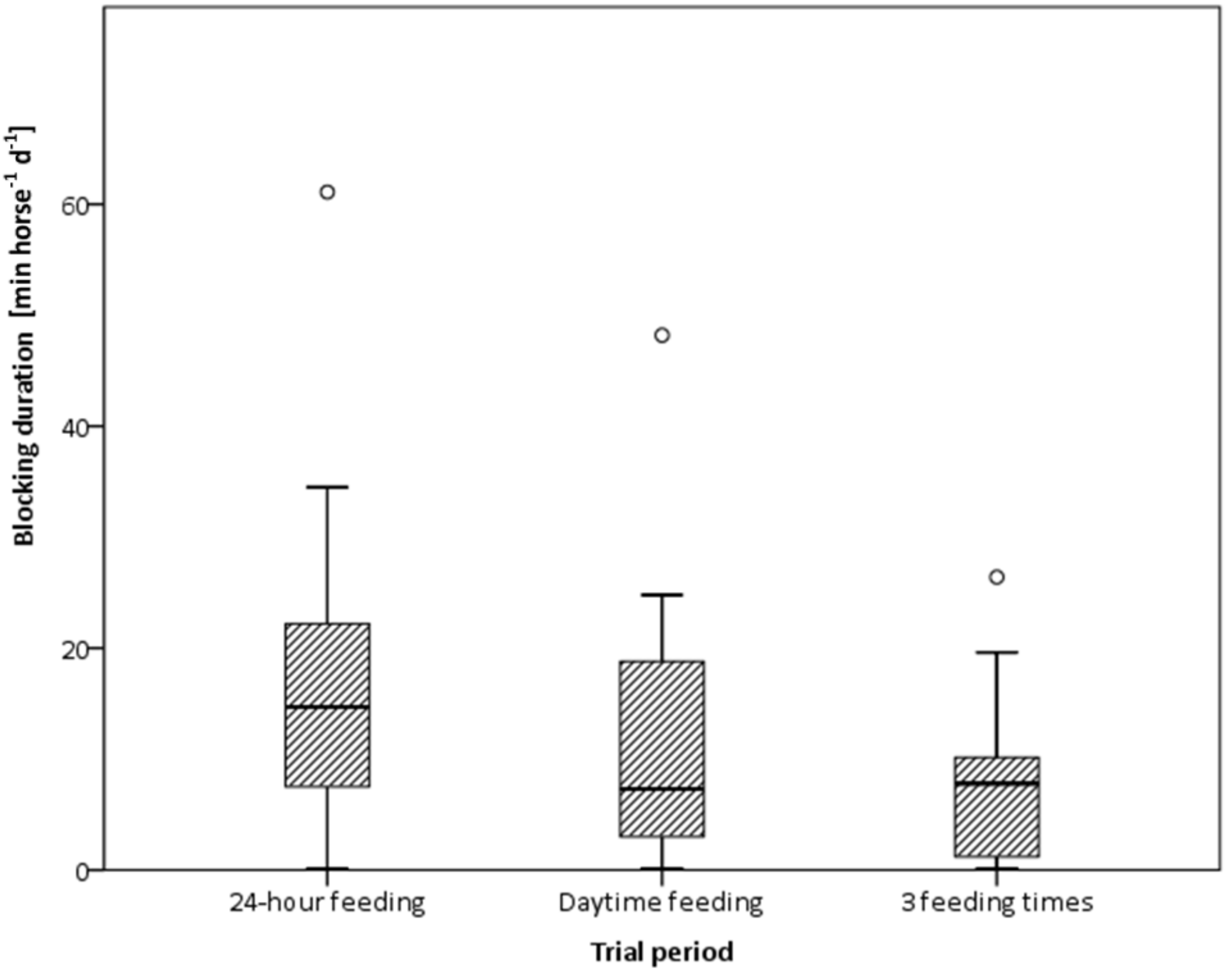

Fig. 3. The daily 'blocking duration' [min horse^{-1} d^{-1}] of the observed 19 horses in the concentrate feeding station during the 3 trial periods. ° represents outliers.

In the 24-hour feeding regime, 87.2% of the station visits were accompanied by blocking times. In the course of the present study, this proportion could be reduced to 82.6% (daytime feeding regime) and 78.2% (3 feeding times). However, this reduction was not statistically significant. The analysis of the individual horses showed that all the observed horses consistently blocked the concentrate feeding station in all trial periods.

The influence of different feeding regimes on the activity behavior of the horses

During the course of this study, the activity behavior of the 19 horses observed increased with the reduction of feeding times. In the 24-hour feeding regime, the average daily activity of the horses was 9740.6 ± 2193.0 activity impulses throughout the day. With the implementation of the daytime feeding regime, the activity behavior of the horses increased significantly ($P < 0.001$) to 11941.4 ± 2574.2 activity impulses. Although the activity of the horses was highest with the application of 3 feeding times (13009.9 ± 2682.8 activity impulses), a significant difference could only be verified for the 24-hour feeding regime ($P < 0.001$) but not for the daytime feeding regime ($P = 0.107$) (Figure 4).

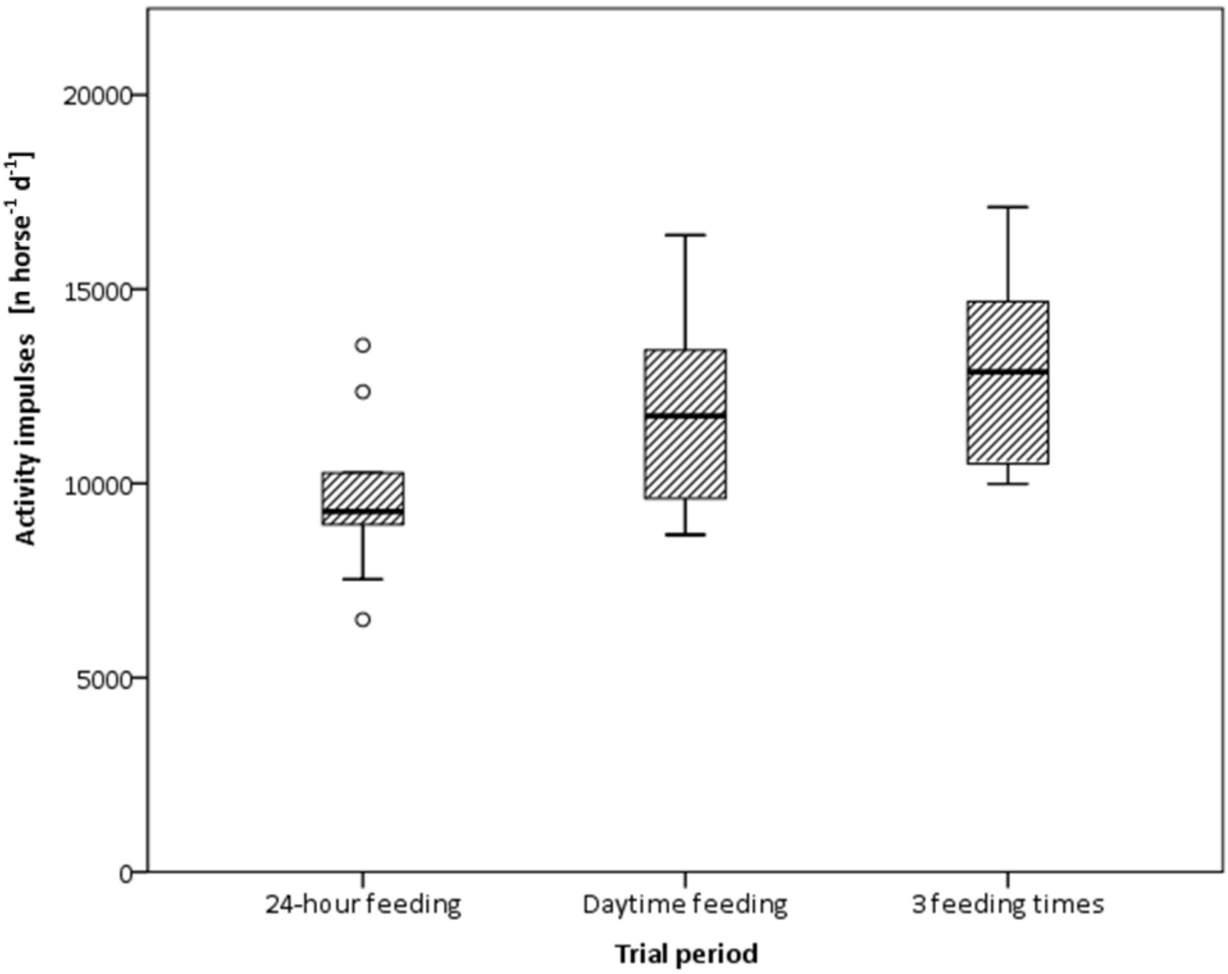

Fig. 4. The activity of the horses during the 3 trial periods measured in activity impulses [n $horse^{-1}$ d^{-1}]. ° represents outliers.

Table 1 shows the average daily activity of the individual horses in the 3 trial periods. The activity of all horses was higher with the implementation of 3 feeding times, when compared with the 24-hour feeding regime. With only 1 exception (horse 2), the recorded activity impulses increased with the reduction of feeding times and were highest under the application of 3 feeding times.

Table 1
Average daily activity impulses of the observed nine horses during the 3 trial periods

Horse	Activity impulses [mean ± s.d.]		
	24-hour feeding	Daytime feeding	Three feeding times
1	9275.0 ± 1697.2	11739.0 ± 1180.1	12867.3 ± 1924.2
2	9113.7 ± 2221.2	11412.0 ± 368.9	10010.0 ± 2177.9
3	7532.0 ± 1009.2	9431.0 ± 506.9	10508.3 ± 2038.7
4	10270.0 ± 676.0	11951.3 ± 132.0	14675.3 ± 643.5
5	6496.0 ± 1122.4	8680.7 ± 631.4	11562.3 ± 1214.5
6	12359.0 ± 1054.5	14830.3 ± 937.6	16194.7 ± 640.5
7	8945.7 ± 1349.0	9612.0 ± 174.7	9988.0 ± 2641.2
8	10119.7 ± 1475.0	13427.5 ± 60.1	14173.7 ± 3233.4
9	13554.5 ± 688.0	16388.5 ± 618.7	17109.0 ± 1824.0

Discussion

This study has shown that the implemented feeding regime did not influence the average number of station visits in the 3 trial periods. The average daily "visit frequency" of the horses ranged from 6.3 ± 3.1 to 7.8 ± 4.1 and was, when compared to the investigations of Zeitler-Feicht et al. (2011) with 18.9 ± 1.8, considerably less frequent. In the 24-hour feeding regime, the horses visited the concentrate feeding station 7.8 ± 4.1 times. Gülden and Büscher (2017) observed an average daily visit frequency of 7.5 ± 3.4 in the trial period status quo (24-hour feeding). Consequently, both studies found out that the horses did not really make use of the opportunity to visit the feeding station every hour.

In contrast to the observed visit frequency, the average daily visit duration in the concentrate feeding station was influenced by the implemented feeding regime. In the 24-hour feeding regime, the observed horses spent on average 28.7 ± 16.4 minutes per day in the feeding station. With the reduction of feeding times, this residence time could be reduced significantly by 30.0% (daytime feeding regime) and 55.7% (3 feeding times). These residence times are relatively low compared to the average daily visit duration of 69.1 ± 4.4 minutes observed by Zeitler-Feicht et al. (2011). Nevertheless, the 19 horses observed in the present study occupied the feeding station for 9.1 ± 0.4 hours throughout the day. Taking into consideration that 30 horses were housed in the investigated active barn shows that the total occupancy time of the concentrate feeding station was even higher. Furthermore, the average daily feeding duration of the observed 19 horses was 9.9 ± 6.3 minutes in the 24-hour feeding regime. Consequently, only 35% of the average daily residence time was spent on feeding. In accordance with the findings of Gieling et al. (2007), the feeding time of the horses was relatively low compared to the observed residence time in the 24-hour feeding regime. Irrespective of the decrease in the observed residence and feeding times of the remaining trial periods, this proportion varied only slightly (daytime feeding regime: 37%; three feeding times: 39%).

The average daily "feeding frequency" and thus, the number of rewarded visits, decreased significantly from 5.5 ± 3.4 (24-hour feeding regime) to 3.7 ± 2.2 (daytime feeding regime) and 1.8 ± 1.2 (3 feeding times) in the course of the present study. For the 24-hour feeding regime, the number of rewarded visits was comparable to the observations of different authors (Gieling et al., 2007; Gülden and Büscher, 2017). As the number of rewarded visits was low compared to the number of possible station visits, the findings of Gieling et al. (2007) and Gülden and Büscher (2017) could be verified in the course of the present study. In the case of the present study, this observation can be explained by the portioning procedure of the concentrate feeding station. The different ingredients of the assigned rations (oats, pellets, cereals, mineral feed) can only be portioned out if the feeding claim comprises at least the minimum proportions mentioned previously. As the average daily feeding claims of the horses were relatively low (472.6 g ± 328.4 g), these minimum proportions were not accumulated every hour. Therefore, the feed could not be portioned out every hour and consequently, the number of rewarded visits was relatively low.

The average daily "feeding duration" decreased significantly with the reduction of feeding times at the investigated concentrate feeding station. In the third trial period (3 feeding times), the average daily "feeding duration" was 50.5% lower than in the 24-hour feeding regime. This reduction cannot be explained by different feeding claims as these differed only marginally between the 3 trial periods. However, it could be observed that the amount of feed that could have been portioned out, but was not picked up by the horses, increased substantially from 589.3 g ± 342.9 g (24-hour feeding regime) to 801.3 g ± 466.7 g (daytime feeding regime) and to 1304.3 g ± 192.1 g (3 feeding times). A possible explanation for the occurrence of these feed remains can be found in the acclimatization period. Maybe the granted acclimatization period of 4 weeks was too short to get used to the new feeding regimes. On the other hand, it could be observed that 66% (24-hour feeding regime), 65% (daytime feeding regime), and 76% (3 feeding times) of the total feed remains in each trial period were left by the same 3 horses. This fact leads to the conclusion that the acclimatization time of 4 weeks was appropriate but that further unspecific aspects are responsible for the feed remains of these 3 horses.

As this study shows, the blocking behavior of the horses can be influenced by different feeding regimes. Although the "blocking frequency" decreased with the implementation of the daytime feeding regime, this reduction was not statistically significant. A significant improvement could only be achieved with the transition to 3 feeding times. Compared to the 24-hour feeding regime, the average daily "blocking frequency" could be reduced by 27.5%.

The average daily "blocking duration" of the horses was 17.6 ± 14.2 minutes in the 24-hour feeding regime. The observed "blocking duration" was comparable to the ones observed by

Gülden et al. (2011) with 14.9 ± 15.9 minutes and Gülden and Büscher (2017) with 15.9 ± 19.2 minutes but considerably lower than the 36.7 ± 128.4 minutes per day and horse recorded in the investigations by Zeitler-Feicht et al. (2011). The average daily "blocking duration" decreased with the reduction of feeding times, but a statistically significant improvement was only achieved with the implementation of 3 feeding times. In comparison with the 24-hour feeding regime, this reduction amounted 56.8%. Nevertheless, the proportion of visits that was accompanied by blocking times was high in each trial period (24-hour feeding regime: 87.2%; daytime feeding regime: 82.6%; 3 feeding times: 78.2%). Furthermore, all the observed horses consistently blocked the feeding station in all trial periods.

ALT pedometers like those used here have been successfully used to investigate the activity behavior of horses in different scientific investigations (Hoffmann et al., 2012; Rose-Meierhöfer et al., 2010). The analysis of the activity data has shown that the activity behavior of horses can be influenced by the feeding regime of concentrate feeding stations. The activity of the horses increased significantly with the reduction of feeding times. Although the activity of the horses was highest with the implementation of 3 feeding times (13009.9 ± 2682.8 activity impulses per horse and day), the average daily number of activity impulses was still lower than in the investigations of Hoffmann et al. (2012) with manual feeding (15957 ± 4001 activity impulses per horse and day). As Hoffmann et al. (2012) discovered, the implementation of a concentrate feeding station led to an increase in the average daily activity (23479 ± 5626 activity impulses per horse and day). Rose-Meierhöfer et al. (2010) found out that the activity behavior of the observed horses differed considerably between 2 investigated active barns (active barn 1: 11308.32 activity impulses; active barn 2: 22366.08 activity impulses) and attributed this to a higher space offer (active barn 1: 225 m^2 per horse; active barn 2: 285 m^2 per horse) and a better arrangement of the functional elements. In the present study, the available area per horse was comparatively low with 116.7 m^2, and the arrangement of functional areas within the housing system can be described as compact. These circumstances might explain the observed activity levels. Rose-Meierhöfer et al. (2010) concluded that the use of concentrate feeding stations can explain the increased activity of horses in active barns compared to horses housed in open barns. Frentzen (1994) as well as Hoffmann et al. (2012) found out that the activity of horses can be increased by a higher feeding frequency. These findings could not be verified in the course of our study. Taking into consideration that the horses were fed through a concentrate feeding station in all trial periods, the activity of the observed horses increased with the reduction of feeding times. As the "visit frequency" was not influenced by the implemented feeding regime, the observed activity increase cannot be explained by an increased number of station visits. More aggressive interactions might be a possible reason for the different activity levels in the 3 trial periods. As the aggressive interactions were not part of the observations, it is not possible to provide a data-based assessment of their effect. Nevertheless, based on a rather personal assessment, the occurrence of aggressive situations can be described as very low in all trial periods. The pasture seems to be negligible as a possible explanation for the different activity levels because the pasture conditions were kept relatively stable throughout the whole study. Based on the collected data, it is not possible to give a reliable answer to the question if the different daylight times in January and May influenced the horses' activity behavior.

Most of the horses housed in active barns are privately owned and are kept for leisure purposes. Owing to age, breed, and training condition, the feeding requirements of these horses usually differ. The feeding claims of all horses housed in the investigated housing system ranged from 0 to 3000 g per day. At the same time, the average daily feeding claims of the horses were relatively low in the 3 trial periods (24-hour feeding regime: 801.7 g ± 773.0 g; daytime feeding regime: 813.3 g ± 798.3 g; 3 feeding times: 774.1 g ± 792.6 g). The main objective of concentrate feeding stations is the feeding of horses according to their individual nutritional needs. Taking into account only nutritional aspects and the recommendations of Meyer and Coenen (2002), horses can be fed up to 4000 g concentrates in 2 portions throughout the day. In practice, the concentrate feeding stations operate throughout 24 hours a day. The main purpose of the applied high-feeding frequency is a higher visit frequency and consequently, an increase in the horses' activity. However, it is often disregarded that in most cases, the horses do not have a feeding claim every hour because of the low total daily feed amounts. Station visits without concentrate allowance are disadvantageous concerning utilization aspects of the concentrate feeding station. In addition, blocking times caused by horses remaining in the feeding station without concentrate allowance increase the utilization of the station. This hypothesis is supported by the observation that the horses spent only 35% to 39% of their residence time on feeding.

Owing to lower investment costs, concentrate feeding stations are increasingly equipped with selection gates. These stations feed and control the horses' access to pasture or roughage areas automatically. Consequently, an occupied station inevitably limits the access to 2 functional areas for the other horses. As low-ranking horses will be affected most, the authors recommend adhering to the separation of functional areas also on the technical level and propose a divided feeding and selecting process instead of its combination within 1 device. Due to the attractiveness of concentrate feed, the well-considered placement of concentrate feeding stations might be a further instrument to increase the horses' activity in active barns.

Conclusions

The reduction to 3 feeding times can be described as advantageous regarding the blocking behavior of the observed horses. The blocking frequency as well as the blocking duration was significantly lowest in this trial period. Nevertheless, the reduced feeding frequency did not reliably prevent the occurrence of blocking times. All horses consistently blocked the concentrate feeding station in all trial periods. Therefore, the authors recommend further scientific research on the occurrence of blocking times. Finding solutions that accord with appropriate animal welfare standards remains a central concern. Due to the desirability of concentrate feed, the application of stimulation devices might be inevitable for some horses.

The reduction of feeding times can also be advised in relation to the activity behavior of the horses. The authors recommend a reasonable reduction of feeding times at concentrate feeding stations based on the feed amount and nutritional aspects. Instead of a high feeding frequency, the space offer as well as the structural design of the active barns should be appropriate means to increase the horses' activity. This approach would also be advantageous concerning the mentioned utilization aspects of the feeding station.

In general, the authors recommend further scientific research on the automated feeding of horses in group housing, due to its influence on central aspects that go beyond the feeding of horses (e.g., activity behavior, stimulation devices, and access authorizations). A holistic approach regarding structural, nutritional, and ethological aspects is advisable.

Acknowledgements

The authors thank the farm manager and the horse owners involved for supporting the investigation. They also thank the Department of Engineering for Livestock Management at the Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB) for generously providing ALT pedometers for this study.

This research was financially supported by the Mehl-Mülhens-Foundation and conducted in cooperation with Schauer Agrotronic GmbH.

Author contribution: The idea for the paper was conceived by AG. The study was designed by AG and WB. The acquisition of data was undertaken by AG and HSZ. AG analyzed the collected data and interpreted it together with HSZ. The paper was written by AG and reviewed by HSZ and WB. All authors have approved the final article for submission.

Ethical considerations

The observations in this study were conducted at the concentrate feeding station of a typical active barn operated under common practice conditions. The housing and handling of the horses by the farm manager and the horse owners were appropriate at all times during the study.

Conflict of interest

The authors declare no conflict of interest.

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4 General Discussion and Conclusions

The current thesis investigated the feeding process at concentrate feeding stations for horses in group housing. The occurrence of blocking times caused by horses remaining in the feeding station without concentrate allowance was of central interest. Analogous to Gülden et al. (2011) and Zeitler-Feicht et al. (2011), these blocking times were proven in both of the studies presented.

The first study investigated the effectiveness of a compressed air stimulus in preventing the occurrence of blocking times. The emergence of blocking times can be described as a very complex issue, with large variations in the behaviour of horses observed. While one horse did not block the feeding station at all, another one did so for more than 2.5 hours throughout one observation day. It was observed that the application of compressed air is a suitable stimulation device for a reasonable proportion of horses. Six horses did not block the feeding station in the short-term as well as in the long-term. Nevertheless, six horses habituated to the compressed air stimulus in the course of the study and the four remaining horses did not respond to the stimulus reliably right from the beginning. This fact clearly points out that the perception of the applied stimulus differs enormously between the horses observed.

The analysis of potential influencing factors did not provide any new findings on that subject. Neither the individual pasture or roughage feeding time nor the total amount of concentrates had a significant influence on the occurrence of blocking times. Furthermore, the blocking behaviour was not influenced by the sex of the observed horses. It was observed that the young horses blocked the feeding station longer than the old and middle aged horses. A statistically significant difference could be proven between the young and middle aged horses in two of the four trial periods. As all of the observed horses were integrated into the active barn more than six months before data collection started, the integration date can be dropped as a possible explanation for this observation. Based on these findings, further scientific research on the identification of potential influencing factors in the emergence of blocking times is recommended.

Due to the desirability of concentrate feed, stimulation devices might be inevitable for some horses. However, the compatibility of the stimulation devices with animal welfare considerations remains an important aspect. The implementation of a stimulus cascade in the course of the drive out procedure can be described as advantageous regarding welfare considerations. Due to the findings of the present thesis, the use of an acoustic signal to indicate the next step of the stimulation cascade can be advised. The temporal succession of the acoustic signal and further stimuli is of crucial importance for a successful learning process. The temporal overlap of the presented stimuli is important to turn a neutral stimulus into a conditioned reinforcer. As it cannot be expected that all farm managers are familiar with the principles of learning theory, two solution strategies can be advised. The implementation of an “off-the-shelf” solution provided by the industry is a possible first approach to a solution. In this case, the farm managers would only have to decide for which horses the stimulation device should be activated. This approach is strongly recommended, as it can easily be put into practice and possible operating and setting errors in the use of stimulation devices caused by the farm managers can be prevented. The second strategy is based on the education and training of farm managers in the reasonable and appropriate application of stimulation devices. This approach would also lead to an improved handling in the use of stimulation devices. Nevertheless, both solution strategies should be based on the principles of learning theory to guarantee a successful learning process for all horses.

In practice, the principle of negative reinforcement is used to prevent the occurrence of blocking times. The application of an electric impulse seems to be the only means to prevent these blocking times reliably, but, at the same time, raises concern regarding welfare implications. The present study has shown that the application of compressed air is suitable as an alternative stimulation device at least for a reasonable amount of horses. In the course of different preliminary tests, several positive and negative reinforcers have been investigated. Among the different negative reinforcers tested, the implementation of a swinging underground also led to encouraging results (Figure 1 and 2). Due to massive reconstruction measures, a final investigation of this stimulation device was not possible. Based on the preliminary tests conducted, it is recommended to install the swinging ground on floor level. Furthermore, it should be ensured that the horses are not able to avoid the stimulus without leaving the station. A problem which occurred in practice was the contamination of the swinging ground caused by the sand being brought into the feeding station. Due to this fact, the swinging ground had to be cleaned very often to ensure a smooth operation. In case a solution can be found that is really feasible, the suitability of the swinging ground could be investigated in a separate test series.

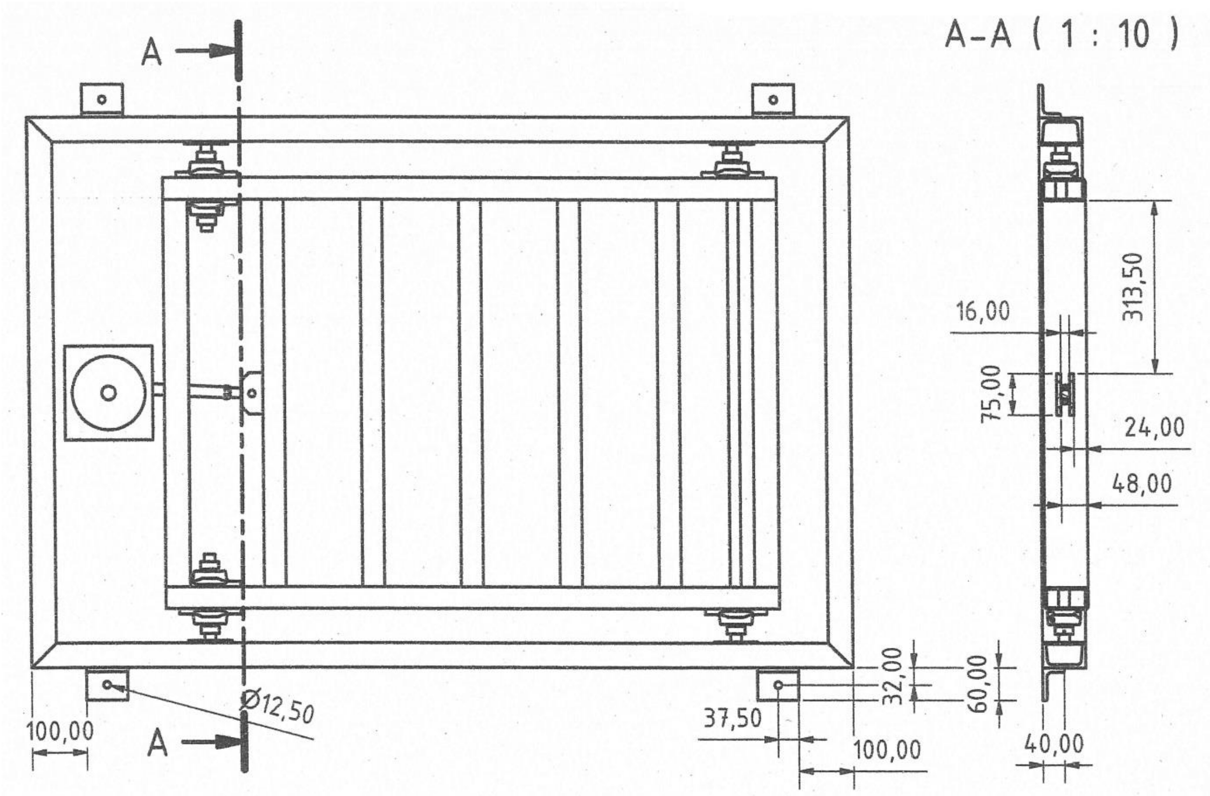

Fig. 1. Design drawing of the implemented swinging ground (dimensions in mm).

Fig. 2. Implementation of the swinging ground into the concentrate feeding station.

According to Zimbardo and Hoppe-Graff (1995), positive reinforcement is more suitable to evoke a new reaction or stabilize an already existing one than negative reinforcement. Zeitler-Feicht et al. (2011) suggest the positioning of the feeding stations exit to provide a view of the roughage feeding area. This approach should motivate the horses to leave the feeding station.

To date, clear scientific evidence supporting this suggestion is not available. In the course of the present thesis, the effect on the horses' blocking behaviour of offering water and a feed reward directly behind the feeding station was investigated in two preliminary tests. The results of these tests lead to the conclusion that full implementation of these measures should not be undertaken without detailed consideration of the disadvantages arising. In conclusion, further scientific research is needed to give a clear and final recommendation on the suitability of potential positive and negative reinforcers to prevent the occurrence of blocking times. Based on the results of the present thesis, the application of compressed air as a part of the drive out cascade can be described as practicable and compliant to appropriate animal welfare standards. However, the suitability of further potential stimuli has not yet been finally investigated. According to the results of the present thesis, it is recommended to reconsider general structural aspects of concentrate feeding stations in this context. It is advised to ensure that the horses are not able to avoid the applied stimuli without leaving the feeding station. At the same time, it should be scrutinized that the horses have to leave the feeding station in a right angle. In case the applied stimulation device triggers a flight reaction, this approach can be regarded as disadvantageous. A substantial improvement would be a station's exit that leads the horses straight ahead instead of forcing them to turn left or right while leaving the station.

The second study investigated the influence of different feeding regimes on the occurrence of blocking times. Therefore, this study pursued a completely different approach to the reduction of blocking times. It was observed that the horses' blocking behaviour is affected by the implemented feeding regime. The horses' blocking frequency and blocking duration was significantly lowest with the implementation of three feeding times. Nevertheless, the adjustment of the applied feeding frequency did not reliably prevent the occurrence of blocking times. Indeed, all horses consistently blocked the feeding station in all trial periods. Furthermore, the proportion of station visits accompanied by blocking times was high in each trial period. Based on these observations, a reasonable reduction of feeding times can only be described as advantageous but not as a successful approach in the prevention of blocking times.

Concentrate feeding stations are associated with a high animal/feeding-place ratio. In practice, these stations are often equipped with a selection gate that controls the access to certain areas (pasture or roughage area). Consequently, the occupancy of the feeding station inevitably restricts the access to different functional areas within the housing system. Based on these facts, the utilisation of the feeding station is of utmost importance to prevent especially the low-ranking horses from disadvantages. The present study shows that the horses' visit duration in the concentrate feeding station was significantly lowest with the implementation of three feeding times. It was observed that the horses only spent 35 % - 39 % of their residence times on feeding. Therefore, the observations of Gieling et al. (2007) could be verified in the course of the present study. Consequently, a reasonable reduction of feeding times can be advised regarding utilisation aspects of concentrate feeding stations.

Both studies revealed that the horses do not really exploit the opportunity to visit the feeding station every hour throughout the day. Additionally, the number of rewarded visits was low compared to the number of possible station visits. Based on these facts, the benefit of high feeding frequencies is also questionable. Instead, it is recommended to focus on the portioning procedure of concentrate feeding stations in further scientific research projects. The horses' feeding claims can only be portioned out if they comprise at least the minimum proportion of the assigned ingredients. In case of pellets for example, this minimum proportion amounted 48 g. If the concentrate feeding station is operating 24 h a day and a horse receives a total amount of 2000 g pellets per day, this horse has an hourly feeding claim. In practice, the assigned rations comprise different ingredients (e.g. oat, pellets, cereals, mineral feed) and most of the horses being fed by means of concentrate feeding stations are leisure horses. Due to this fact, the horses' individual and total feed amounts per day are much smaller. Consequently, the horses do not have an hourly feeding claim. As the horses cannot anticipate an existing feeding claim while entering the feeding station, the feeding process appears to be rather arbitrary for the horses. As the horses might expect further feed to be provided, this approach might contribute to the occurrence of blocking times. Furthermore, the feeding portions not being picked up are accumulated until the horse enters the concentrate feeding station again. In conclusion, the horses receive more feed in case of few station visits. These arguments point out that concentrate feeding stations would also benefit from a fundamental reconsideration of the portioning procedure.

The second study also investigated the argument that high feeding frequencies at concentrate feeding stations lead to increased activity behaviour of the observed horses. Indeed, it could be observed that the implemented feeding regime influences the horses' activity behaviour. But, in contrast to the current state of knowledge, the horses' activity behaviour increased significantly with the reduction of feeding times. Consequently, a reasonable reduction of feeding times can also be advised regarding the horses activity behaviour. This reduction should focus on the horses' total feed amount and general nutritional aspects.

Based on the findings of the present thesis, high feeding frequencies at concentrate feeding stations cannot be described as a successful approach without certain disadvantages arising. Besides a generous space offer and the structural design of the housing system, a well-considered placement of concentrate feeding stations seems to be a more suitable approach in order to increase the horses' activity behaviour. As concentrate feed is very attractive for horses, the placement of concentrate feeding stations in spatial distance to other functional areas of the group housing system can be used to generate extended walking routes. This approach would inevitably increase the horses' activity behaviour. Furthermore, a divided feeding and sorting process instead of its combination within one device is strongly recommended. The placement of sorting devices, controlling the horses' individual access to pasture or roughage areas, in maximum distance to the concentrate feeding station can be advised to increase the horses' activity behaviour.

Based on the arguments and considerations described above, further scientific research on the use of concentrate feeding stations is strongly advised. As automatic feeding stations influence central aspects that go far beyond the feeding of horses (e.g. activity behaviour, stimulation devices, access authorities), the interdisciplinary teamwork of ethologists, professionals in animal nutrition and development engineers is strongly recommended.

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Danksagung

Ich möchte mich herzlich bei allen bedanken, die zum Gelingen dieser Arbeit beigetragen haben.

Mein besonderer Dank gilt Herrn Prof. Dr. Wolfgang Büscher für die Überlassung des Themas, die wissenschaftliche Betreuung und seine uneingeschränkte Unterstützung als Doktorvater.

Herrn Prof. Dr. Karl Schellander danke ich sehr für die Übernahme des Korreferates.

Mein besonderer Dank gilt der Mehl-Mülhens-Stiftung für ihr Interesse an dem Forschungsprojekt und die gewährte finanzielle Förderung.

Ausdrücklich danken möchte ich auch der Firma Schauer Agrotronic GmbH sowie ihren Mitarbeiterinnen und Mitarbeitern für die Zusammenarbeit und die engagierte Diskussionsbereitschaft.

Ein herzliches Dankeschön richte ich an Herrn Thomas Rolland für seine aufgeschlossene Haltung gegenüber neuen Versuchsansätzen sowie sein tatkräftiges und uneingeschränktes Engagement in der Versuchsdurchführung auf seinem Betrieb.

Bei allen Pferdebesitzern bedanke ich mich für die gewährte Unterstützung, ohne die die Arbeit letztlich nicht möglich gewesen wäre.

Mein besonderer Dank gilt Helene Schulze Zurmussen für ihre ausgezeichnete Arbeit als studentische Hilfskraft. Vielen Dank für die konstruktiven Gespräche und die tatkräftige Unterstützung bei der Datenerhebung.

Dem Leibniz-Institut für Agrartechnik und Bioökonomie danke ich für die Leihgabe der ALT-Pedometer. Mein Dank gilt insbesondere Frau Dr. Gundula Hoffmann und Herrn Ulrich Stollberg für die Hilfsbereitschaft in allen Fragen rund um die ALT-Pedometer.

Herrn Prof. Dr. Josef Troxler von der Veterinärmedizinischen Universität Wien danke ich herzlich für die gewährte Unterstützung bei ethologischen Rückfragen.

Bedanken möchte ich mich ebenfalls bei Frau Martina Warnken vom Hochschulrechenzentrum der Universität Bonn für die konstruktive Beratung bei statistischen Nachfragen.

Meinen Kollegen vom Institut für Landtechnik danke ich für die angenehme Arbeitsatmosphäre und die schöne gemeinsame Zeit.

Tim Durant sowie den Englischlehrern in meinem Familien- und Freundeskreis Ina Durant, Anne Gülden und Tim Gülden gilt mein allergrößter Dank für die investierte Zeit und die sprachliche Aufwertung der Arbeit.

Mein herzlichster Dank gilt meiner Familie und meinen Freunden, insbesondere meiner besten Freundin Susanne Grundei, für den Rückhalt, die Motivierung und das in mich gesetzte Vertrauen in allen Phasen meiner Promotion. Ohne die andauernde Unterstützung meiner Mutter hätte mich mein Bildungsweg nicht nach Wien und schlussendlich nicht zur Promotion geführt. Meinem Ehemann Ben Gülden bin ich unendlich dankbar für seine uneingeschränkte Unterstützung sowohl praktischer, fachlicher als auch emotionaler Natur. Seine Art mich zu erden und zu motivieren ist einmalig.