Applied Animal Behaviour Science 117 (2009) 159–164

Contents lists available at ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Dairy cows trade-off feed quality with proximity to a dominant individual in Y-maze choice tests

Fiona C. Rioja-Lang [a,*], David J. Roberts [a], Susan D. Healy [b], Alistair B. Lawrence [a], Marie J. Haskell [a]

[a] Scottish Agricultural College, King's Buildings, West Mains Road, Edinburgh, EH9 3JG, United Kingdom
[b] The University of Edinburgh, Ashworth Laboratories, Kings Buildings, West Mains Road, Edinburgh, EH9 3JT, United Kingdom

ARTICLE INFO

Article history:
Accepted 9 December 2008
Available online 24 January 2009

Keywords:
Feeding behaviour
Y-maze
Choice
Dairy cows

ABSTRACT

In this experiment choice tests were used as a tool to determine how dairy cows perceive their feeding environment with specific emphasis on understanding the challenges that low ranking animals face when forced to feed in the presence of socially dominant cows. It was hypothesised that cows would trade-off proximity to a dominant individual at the feed-face with access to food of a high quality. Thirty Holstein Friesian cows were used in the study. A test pen contained a Y-maze, with one black feed bin placed in one arm of the maze and one white feed bin placed in the other arm. During a training phase half of the cows were trained to make an association between the black bin and high quality food (HQF), and the white bin and low quality food (LQF). The other half was trained with the opposite combination, to prevent any colour bias. The status of each cow was assessed and dominant and subordinate cows were paired. Choice test 1 determined if cows had correctly learned the association between colour (of food bin) and food quality. Cows were presented with one black and one white bin in the two arms of the maze, with the presentation of each coloured bin in the left and right arms randomised. When cows achieved an 80% success rate of HQF preference they proceeded onto the next stage, where two further tests were presented. In choice test 2, the subordinate cow was presented with two bins of HQF, one of which had a dominant cow feeding from it. In test 3, cows had a choice of HQF and LQF, with the dominant cow present at the HQF bin. Cows showed a significant preference for feeding on HQF alone rather than next to a dominant ($P < 0.001$). When they were "asked" to trade-off feed quality with feeding next to a dominant, the majority chose to feed alone on LQF ($P < 0.01$). These results suggest that social status within a herd could significantly affect feeding behaviour, especially in situations of high competition and for subordinate individuals.

1. Introduction

In recent years there has been an increasing concern over the issue of farm animal welfare. One reason underlying this concern is the belief that many modern livestock production systems do not allow animals to perform a natural range of behaviours leading to a possible decline in welfare. One method of determining the importance of these behaviours is to perform choice tests. The results of such assessments are useful for making recommendations regarding animal husbandry, and thus, aiming to improve animal welfare (see Dawkins, 1980; Dawkins, 1983, for a review). In this study, choice tests were used to assess feeding behaviour in dairy cows.

Feed intake in dairy cows is directly related to milk production, particularly the dry matter intake (DMI) which

* Corresponding author. Tel.: +44 131 535 3058.
E-mail address: Fiona.Lang@sac.ac.uk (F.C. Rioja-Lang).

0168-1591/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.applanim.2008.12.003

is the main factor contributing to production. A good feed supply is particularly important to the modern, high yielding dairy cow and insufficient quality or quantity of feed can lead to excessive liveweight loss and associated health and welfare problems. In the UK, advances in genetics and improved management practices have resulted in a rapid increase in milk production. The current average yield in the UK is around 7000 L per cow per annum (DairyCo, 2008). This figure is almost seven times the required volume of milk of a cow suckling a calf. This massive increase in milk yield has led to dairy cows having considerably increased nutrient requirements in order to maintain this level of production.

A well-designed management system should adequately accommodate optimal feeding behaviour i.e. cows prefer to eat in frequent, short bouts (Grant and Albright, 1995) during specific times of day: on return from milking and after delivery of fresh feed. However, the intensification of dairy production systems has resulted in animals often competing for resources (Albright, 1993). Factors that appear to limit access to feed include not only physical aspects (i.e. building design, feed barrier, etc.) but also social factors. Social dominance has practical importance if dominance relationships result in certain animals consistently losing out on access to important resources (Grant and Albright, 2001). Competition for feed can increase the rate of agonistic interactions and can also reduce feed intake of certain individuals. Factors that influence the level of competition include manipulations of management e.g. ad libitum or restricted feeding (Olofsson and Wiktorsson, 2001), feeding frequency (De Vries et al., 2005; Oostra et al., 2005), grouping (Grant and Albright, 2001) design of facilities (Collis et al., 1980; De Vries et al., 2004) stocking rate (Huzzey et al., 2006) and equipment, such as partitions (Herlin and Frank, 2007). A restricted feeding area most likely favours cows that are high in social rank. The consequences of experiencing high levels of competition at the feed-face could result in subordinate animals altering their daily activity patterns in order to maintain adequate levels of feed e.g. spending less time ruminating and lying, and increasing the length of feed bouts which can increase the risk of metabolic disorders. Social stress, such as over crowding and excessive competition for feed, can significantly reduce rumination activity (Batchelder, 2000). Dominant cows may also sort the total mixed ration (TMR) (De Vries et al., 2005) preferring the grain concentrate component and leaving less desirable forage components. Sorting can reduce the nutritional quality of the remaining feed which is then consumed by lower ranking individuals feeding outside of peak feeding times. Cows that are unable to access the feed-face at peak feeding times may not maintain adequate nutrient intake to meet their energy requirements (Hosseinkhani et al., 2008).

By observing and understanding how cows behave at the feed-face it should be possible to design a feed barrier (the physical divide between cattle and feed) that reduces competition and maximises feed intake. Previous approaches have largely involved group studies (e.g. Friend et al., 1977; Huzzey et al., 2006; Kondo et al., 1989; Lang et al., 2007) focussing on the effects of stocking density on aggressive interactions. This study uses a choice test approach to examine the choices faced by cows at the feed-face. Choice tests require animals to choose between two or more different options or environments (Fraser and Matthews, 1997). In dairy cows, choices relating to various treatments, including feeding, shouting, electric shock, hitting (Pajor et al., 2003) and being milked (Prescott et al., 1998) have been assessed using Y-maze methodology. This process involves training individual animals to anticipate receiving a treatment if they enter one arm and an alternative treatment if they enter the other arm (Pajor et al., 2003). An animal is generally thought to prefer an option if it spends more time with it and/or chooses it more often.

In this instance, choice tests were used as a tool to determine how dairy cows perceive their feeding environment with specific emphasis on understanding the challenges that low ranking animals face when forced to feed in the presence of socially dominant cows. It was hypothesised that cows would trade-off proximity to a dominant individual at the feed-face with access to food of a high quality.

2. Materials and methods

2.1. Animals and housing

Forty-two lactating Holstein Friesian cows were used in the study. Twelve cows were used as part of a pilot study, and 3 groups of 10 were used for the actual experiment. Half of the cows were multiparous (parity = 3.4 ± 0.5; mean $\pm$ S.D.) and half were primiparous. All cows were housed in a cubicle shed at the SAC Dairy Research Centre, Dumfries, UK. Animals were separated from the rest of the herd 24 h before experimental procedures began. They were housed in a separated area of the cubicle housing within the main shed where they had access to feed and water. After testing sessions, animals were returned to the cubicle area where they had access to a TMR formulated to provide adequate nutrients for maintenance and milk production. The animals were not fed any additional concentrates during milking. Fresh feed was delivered once a day (whilst the animals were being tested in a separate area) and they generally had access to it within about 1 h of their normal feeding time.

2.2. Test procedure and testing arena

All testing was carried out between the hours of 08.00 and 12.00. After morning milking the cows were taken to a large straw holding pen, situated next to the test pen. The cows remained in this holding pen with free access to water but with no access to feed until the testing sessions were complete. When each cow was to be tested they were moved individually by a handler from the holding pen and held at the top of the passage. The cow was allowed to walk down the full length of the passage ($\sim$30 m) towards the test pen. The animals were not rushed and they were only given gentle encouragement if they did not make their way

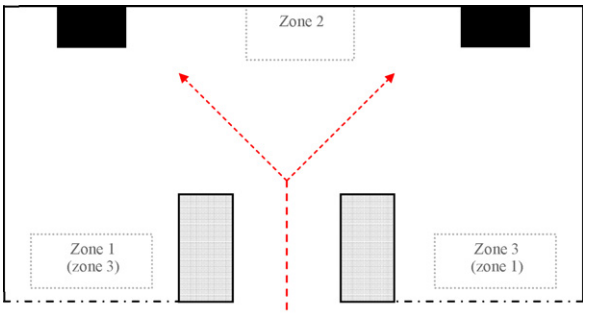

Fig. 1. Diagram of test arena, including starting entrance, 3 zones and position of feed bins.

in the correct direction. Two handlers were present during all sessions. Handlers all wore the same colour of overalls and stood in the same positions for each test (outside the test area).

The Y-maze was inside the test arena (Fig. 1) and consisted of a single alley (1.2 m long) with two arms (3.65 m long), one to the left and one to the right. At the end of each arm either a black or white feed bin (0.75 m × 0.55 m × 0.58 m) and a sheet of plastic of corresponding colour mounted on the wall (0.60 m × 0.45 m). Both boards were visible to the cow as she entered the Y-maze. The arms of the maze were not formally penned off. Instead, the idea of the shape was defined using crates to form the base of the 'Y', with the position of the feed bins representing the arms. The walls of the test pen were made from brick and solid wood so that animals in the pen were visually isolated from pen-mates and other distractions within the shed. The arena was classified as having 3 separate zones so that the location of the cows could be recorded during testing.

2.3. Dominance testing

Animals were allocated to pairs consisting of a dominant and subordinate animal. To assess the dominance of each cow an index was constructed from interactions observed at the feed-face in the cubicle area. Displacements were recorded at a post and rail feed barrier during the 30 min period after the delivery of fresh feed and after the afternoon milking for 5 consecutive days. These two recording periods were selected as they have been shown to be the times when most cows are present at the feed-face and the highest level of competition (De Vries et al., 2003). A displacement was noted when a cow's head (actor) came in contact with a cow that was feeding (reactor), resulting in the reactor withdrawing its head from the feed-face, as described in Huzzey et al. (2006). The number of displacements per cow was used to measure the competitive behaviour of cows at the feed-face. These observations were used to calculate an 'index of success' from agonistic interactions of each individual cow using the methods described by Mendl et al. (1992). This was calculated by dividing the number of cows that an individual was able to displace, by the number of cows that and individual was able to displace plus the number of cows that were able to displace the individual, all multiplied by 100. This method has previously been used to assign dominance in a number of dairy cattle studies (Mendl et al., 1992; De Vries et al., 2004; DeVries and von Keyserlingk, 2006). From within each group of 10 animals, cows were assigned a rank from 1 to 10 with 10 being the most dominant. Aiming to maintain a significant level of dominance between pairs, cows were paired 10–5, 9–4, 8–3, etc. In cases where observations did not resolve dominance, pairs were presented with a line of concentrate feed in an open space. Aggressive interactions were recorded and the success index was calculated.

2.4. Training procedure

The training phase consisted of 4 consecutive days, followed immediately by a testing period of 2–4 days. All of these procedures were carried out in the same test arena. Half of the cows were randomly assigned to be trained to associate a black feed bin as containing high quality food (HQF) and a white bin as containing low quality food (LQF). The other half was trained with the opposite combination. The HQF was a concentrate pellet, and the low quality feed was a mix of rolled barley (82%) and soya (18%). These feeds were chosen as they have been acknowledged to be of high and low palatability, but have similar levels of metabolisable energy (ME) and crude protein (CP). Concentrates are highly valued by cows and are therefore a cause for competition and aggression (Herlin and Frank, 2007). The feed chosen was also familiar to dairy cows, as it is a component of their regular TMR. This familiarity prevented the introduction of any novel foods that might alter feeding behaviour due to neophobia. Both dominant and subordinate cows were trained, even though it was only the subordinate cows that were going to be tested. This allowed all of the cows to become familiar with the arena and equipment.

The cows were individually brought into the test arena and presented with only one bin of either high or low quality food, in either the black or white bin, on the right or left hand side of the pen. These presentations were in a randomised order to prevent animals from predicting choices. Each cow had two non-consecutive training tests per day for 8 days, each of which lasted for a period of about 5 min (this was the average length of time it took to consume the 0.5 kg meal).

2.5. Testing procedures

2.5.1. Test for association between feed quality and bin colour (choice test 1)

After training, the animals were tested to evaluate if they could correctly make an association between the feed quality and the colour of the bin. Each cow was presented with both feeds together (on either arm of the 'Y') to determine if they could consistently choose the bin containing the high quality feed. Their choice was recorded as being the bin they took the first mouthful of feed from. Cows were removed after they had either finished the feed from the bin of their choice (either high or low) or the 5 min time limit had elapsed. If an animal had made a wrong choice initially, then moved to feed from the correct feed bin before 3 min, they were given a limit of 30 s to feed

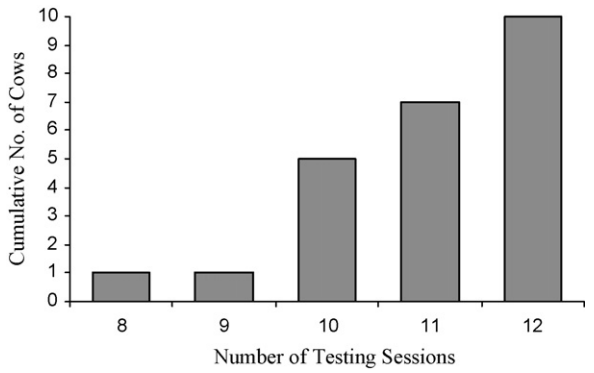

Fig. 2. Choice test 1: cumulative number of cows that reached success criterion of 8 correct choices out of 10 in consecutive sessions.

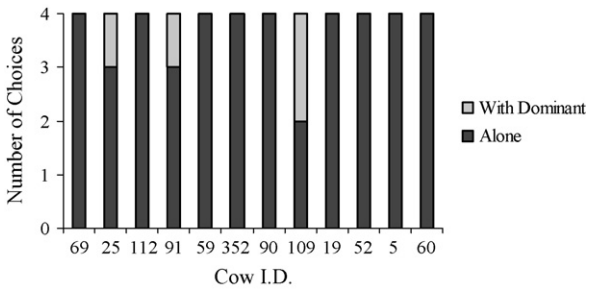

Fig. 3. Choice test 2: subordinate cows given choice of feeding on high quality food alone or next to dominant cow.

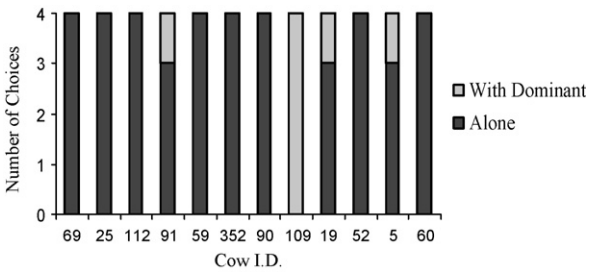

Fig. 4. Choice test 3: subordinate cows given choice to trade-off feed quality with feeding alone or next to dominant cow.

before being removed from the arena. However, if they changed their decision after 3 min, they were removed from the pen immediately. The aim of this criterion was to allow cows to correct their choice (within 3 min) if they initially approached the wrong bin, but to prevent animals learning that eating both feeds was an option. If a cow initially chose the wrong bin and moved within 3 min, this was still counted as an 'incorrect' choice.

Table 1
Sign tests for difference between choices of each choice test.

	N	Below	Equal	Above	*P*
Choice test 2	12	0	1	11	<0.001
Choice test 3	12	1	0	11	<0.01

Table 2
Wilcoxon signed ranks test for differences between choices over both choice tests.

Test	*N*	*Z*	*P*
Choice test 2 and 3	12	8	>0.05

2.5.2. Choice test between feeding alone or next to a dominant

Choice test 2 involved the subordinate cows being presented with a bin of HQF at both arms of the Y-maze, one of which had a dominant cow feeding from it. The amount of time that a subordinate cow spent in each area of the arena was also recorded. The aim of this was to identify if subordinate cows were actually choosing to feed alone or they were being blocked by the dominant cow. The test arena was split into 3 zones (Fig. 1). These zones represented the side the dominant cow was occupying (1), the middle area (2), and the unoccupied area (3). Each cow was tested 4 times over 4 days, and the location of the dominant cow was randomised over the trials.

2.5.3. Trade-off choice test between feed quality and proximity to a dominant

Choice test 3 offered a trade-off situation between food quality and proximity to a dominant individual. Subordinate cows had to make a choice between HQF and LQF, with the dominant cow present at the HQF bin. Each cow was tested 4 times also over 4 days, and the location of the dominant cow was also randomised.

2.6. Data collection and statistical analyses

For each choice test the number of times an individual cow chose each option was recorded. Sign tests were used to test for a significant difference between the number of times an option was chosen ($P < 0.001$). Wilcoxon signed ranks tests were used to test the significance of the difference between the choices made in choice test 2 and choice test 3 ($P < 0.05$).

3. Results

In choice test 1, all cows were tested to determine if they could correctly and repeatedly choose the high quality food, when offered both qualities at the same time. The number of tests for individuals to reach the criteria of 8 consecutive correct choices from 10 testing sessions is displayed in Fig. 2. One pair from each group of 10 that did not reach the criteria was dropped from the entire study. Cows showed that they had been successfully conditioned to associate colour with feed quality, and that they preferred the concentrate pellets (HQF) to the barley/soya mix (LQF).

For choice tests 2 and 3, the number of times an individual cow chose LQF or HQF (in the left or right arm of the Y-maze) was recorded (Figs. 3 and 4). The majority of cows (75%) always chose to feed on HQF alone rather than next to a dominant individual. Only 2 cows chose to feed alone in 3 out of the 4 trials, and 1 cow chose to feed alone in 2 out of the 4 trials. Fig. 4 shows the results of the trade-off choice (choice test 3) between feed quality and

proximity to a dominant cow. Sixty-seven percent of cows always chose to feed alone on LQF. 25% chose to feed alone 3 times out of 4 trials and 1 cow always chose to feed next to the dominant cow on HQF.

Cows preferred (Table 1) feeding alone rather than next to a dominant when they were offered high quality feed on both sides of the Y-maze ($P < 0.001$). They also showed a significant preference when they were "asked" to trade-off food quality and proximity to a dominant cow ($P < 0.01$). A Wilcoxon signed ranks test was performed between the choices made from test 2 and test 3 (Table 2). Choice test 2 acted as a baseline, identifying that cows would rather feed alone than next to a dominant cow regardless of feed quality. There was no significant difference ($P > 0.01$) in preference in choice test 3 i.e. even in the trade-off situation, cows still chose to feed alone. The amount of time that a subordinate cow spent in each zone of the arena was also recorded. Subordinate cows spent 83% of their time standing alone in the test arena, 5% of time was spent in the middle, and 12% was spent standing in the same side as the dominant cow.

4. Discussion

Low status cows showed a marked preference for feeding alone rather than next to a dominant individual. Low status cows also traded-off food quality for feeding alone rather than next to a dominant cow. The purpose of the choice test was to examine the importance of social status of herd mates on feeding choices. Choice test 2 involved the test animals receiving the same quality of feed at both arms of the Y-maze, therefore the results suggest that the presence of the dominant cow must create a considerable level of influence over the choice. For the trade-off test (choice test 3), cows are ranking social pressure of the presence of a dominant, even more important than food quality, despite the obvious importance of nutritional intake. The results suggest that proximity between individuals is an important factor whilst feeding, especially for low status cows. Previous studies have also shown that when provided with more space at the feeder, cows increased distances from their nearest neighbour, reduced their frequency of aggressive interactions, and increased feeding activity (De Vries et al., 2004). The large majority of cows in the study agreed in their preferences. Almost all of the cows trained in the study succeeded in learning the association between colour and feed quality with relative ease. Similar successful learning performances have been reported in cows before (e.g. Pajor et al., 2003; Arnold et al., 2007) supporting the effectiveness of this type of approach with farm species.

There were occasions when cows did not choose to trade-off feed quality and one individual never did this. We have no explanation for these events; however some individual variation in relative social dominance within the pair is to be expected, perhaps due to underlying factors such as pre-clinical disease affecting social or feeding behaviour.

The percentage of time that a test cow spent in specific zones of the arena was recorded to determine if cows were actively choosing to feed from their preferred bin, or the dominant cow was aggressively preventing access. Over all of the test period 83% of cows remained within the area of their chosen feed bin. Twelve percent of the overall time spent in the test arena was spent in the same zone as the dominant cow. The distribution of locations suggests that most cows always chose to feed alone, and only on a few isolated occasions would a low status cow not feed with the dominant because she was physically restricted from doing so by the dominant herself.

Y-maze tests are a widely used tool for assessing animal welfare; however they have generally been restricted to smaller species such as rodents and chickens probably due to easier manoeuvrability of the animals and that the apparatus being easier to construct and set-up. As far as we are aware there are only a very limited number of studies using this method with cattle (Pajor et al., 2003; Prescott et al., 1998; Hosoi et al., 1995; Grandin et al., 1994) and never before to look at the effect of social dominance at the feed-face. The options offered within this experiment reflect a realistic situation of the social pressure that cows experience on a daily basis whilst feeding. The options offered were chosen to replicate normal feeding environments, hopefully avoiding the potential pitfalls of offering the wrong options in a choice test.

Testing animals individually, as in this study, allows greater control over the delivery of treatments compared to testing individuals in a group situation. Testing individuals as part of a feeding behaviour study in a group situation may not always allow all animals to have the same access to feed due to social and physical restraints. Although there is a comprehensive body of literature explaining what happens when various aspects of the feeding environment are manipulated, the present choice test approach is very complimentary in explaining what is happening at cow level. It has the potential to explore hypotheses raised in other feeding behaviour studies to provide greater understanding of dairy cow behaviour. In the context of this study, preference testing has provided a novel approach to highlighting specific problems that subordinate animals are confronted with at the feed-face; especially during periods of high competition. Some current housing and feeding designs in the UK are not efficient enough or suitable for present dairy farming. The modern dairy cow is significantly larger than 30 years ago, when much of the existing accommodation was constructed. The problem is compounded by an increase in average herd size without farmers taking due account of the need to increase the size of the housing facilities (DEFRA Report, 2006) The information gained from this study can be used in conjunction with other quantitative studies recommending alterations to various aspects of the feeding environment, including space allowance (Lang et al., 2007), feed barriers (Huzzey et al., 2006) and stocking density (Kondo et al., 1989) and used to design an improved feeding environment. By designing an improved feeding system, producers should be able to maximise efficiency of production and improve cow comfort and welfare. This experimental technique could also be used to identify the different physical and environmental factors

that low status cows use to make their decision. For example the behaviours observed in this study could vary by altering factors such as space allowance at the feed-face, food quality and stage of lactation. By creating a comfortable and suitable feeding environment, for all cows within a group, it should be possible to maximise feed intake and improve production and welfare.

5. Conclusion

Low status cows preferred to feed alone than next to a dominant animal when the same quality of food was offered. When they were asked to trade-off feed quality with feeding next to a dominant animal, the majority still chose to feed alone on low quality food. These results suggest that social status within a herd could significantly affect feeding behaviour, especially in situations of high competition and for subordinate individuals.

Acknowledgments

Financial support for this experiment was provided by the Scottish Government. The authors would like to thank the technical and farm staff at SAC Dairy Research Centre, Crichton Royal Farm, particularly Ainsley Bagnall, David Bell and John Dickinson.

References

Albright, J.L., 1993. Nutrition, feeding and calves. Feeding behaviour of dairy cattle. J. Dairy Sci. 76, 485–498.
Arnold, N.A., Ng, K.T., Jongman, E.C., Hemsworth, P.H., 2007. The behavioural and physiological responses of dairy heifers to tape-recorded milking facility noise with and without a pre-treatment adaptation phase. Appl. Anim. Behav. Sci. 106, 13–25.
Batchelder, T.L., 2000. The impact of head gates and over-crowding on production and behaviour patterns of lactating dairy cows. In: In Dairy Housing and Equipment Systems. Managing and Planning for Profitability, Natural Resource, Agriculture, and Engineering Service Publ., 129, Camp Hill, PA.
Collis, K.A., Vagg, M.J., Gleed, P.T., Copp, C.M., Sansom, B.F., 1980. The effects of reducing manger space on dairy cow behaviour and productions. Vet. Rec. 107, 197–198.
Dairy Co Datum website, 2008. http://www.dairycodatum.org.uk/averagemilkyields.
Dawkins, M.S., 1980. Animal Suffering: The Science of Animal Welfare. Chapman and Hall, London, UK.
Dawkins, M.S., 1983. The current status of preference tests in the assessment of animal welfare. In: Baxter, S.H., Baxter, M.R., MacCormack, J.A.D. (Eds.), Farm Animal Housing and Welfare. Martinus Nijhoff Publishers, The Hague, The Netherlands, pp. 20–26.
De Vries, T.J., von Keyserlingk, M.A.G., Weary, D.M., Beauchemin, K.A., 2003. Measuring the feeding behaviour of lactating dairy cows in early to peak lactation. J. Dairy Sci. 86, 3354–3361.
De Vries, T.J., von Keyserlingk, M.A.G., Weary, D.M., 2004. Effect of feeding space on the inter-cow distance, aggression, and feeding behaviour of free-stall housed lactating dairy cows. J. Dairy Sci. 87, 1432–1438.
De Vries, T.J., von Keyserlingk, M.A.G., Beauchmenin, K.A., 2005. Frequency of feed delivery affects the behaviour of lactating dairy cows. J. Dairy Sci. 88, 3553–3562.
DeVries, T.J., von Keyserlingk, M.A.G., 2006. Feed stalls affect the social and feeding behaviour of lactating dairy cows. J. Dairy Sci. 89, 3522–3531.
DEFRA Report, 2006. Action on animal health and welfare: housing themodern dairy cow. http://www.defra.gov.uk/animalh/welfare/farmed/advice/moderndairycow.pdf.
Fraser, D., Matthews, L.R., 1997. Preference and motivation testing. In: Appleby, M.C., Hughs, B.O. (Eds.), Animal Welfare. CAB International, Wallingford, UK.
Friend, T.H., Polan, C.E., McGilliard, M.L., 1977. Free stall and feed bunk requirements relative to behaviour, productions and individual intake in dairy cows. J. Dairy Sci. 60, 108–116.
Grandin, T., Odde, K.G., Schutz, D.N., Behrns, L.M., 1994. The reluctance of cattle to change a learned choice may confound preference tests. . Anim. Behav. Sci. 39, 21–28.
Grant, R.J., Albright, J.L., 2001. Effect of animal grouping on feeding behaviour and intake on dairy cattle. J. Dairy Sci. 84, 156–163.
Grant, R.J., Albright, J.L., 1995. Feeding behaviour and management factors during the transition period in dairy cattle. J. Anim. Sci. 73, 2791–2803.
Herlin, A.H., Frank, B., 2007. Effects of protective gates and concentrate feed stations on behaviour and production in dairy cows: a brief note. Appl. Anim. Behav. Sci. 103, 167–173.
Hosoi, E., Swift, D.M., Rittenhouse, L.R., Richards, R.W., 1995. Comparative foraging strategies of sheep and goats in a T-maze apparatus. Appl. Anim. Behav. Sci. 44, 37–45.
Hosseinkhani, A., DeVries, T.J., Proudfoot, K.L., Valizadeh, R., Veira, D.M., 2008. The effects of feed bunk competition on the feed sorting behaviour of close-up dry cows. J. Dairy Sci. 91, 1115–1121.
Huzzey, J.M., De Vries, T.J., Valois, P., von Keyserlingk, M.A.G., 2006. Stocking density and feed barrier design affect the feeding and social behaviour of dairy cattle. J. Dairy Sci. 89, 126–133.
Kondo, S., Sekine, J., Okubo, M., Asahida, Y., 1989. The effect of group size and space allowance on the agonistic and spacing behaviour of cattle. Appl. Anim. Behav. Sci. 24, 127–135.
Lang, F.C., Roberts, D.J., Haskell, M.J., 2007. British society for animal science. In: Conference Proceedings. Investigating the Effect of Feeding Space on Aggression, Feeding Behaviour and Production. p. 37.
Mendl, M., Zanella, A.J., Broom, D.M., 1992. Physiological and reproductive correlates of behavioural strategies in female domestic pigs. Anim. Behav. 44, 1107–1121.
Olofsson, J., Wiktorsson, H., 2001. Competition for total mixed diets fed restrictively using one or four cows per feeding station. Acta Agric. Scand. Sect. A: Anim. Sci. 51, 59–70.
Oostra, H.H., Stefanowska, J., Sallvik, K., 2005. The effects of feeding frequency on waiting time, milk frequency, cubicle and feeding fence utilisation for cows in an automatic milking system. Acta Agric. Scand. Sect. A 55, 158–165.
Pajor, E.A., Rushen, J., de Passille, A.M.B., 2003. Dairy cattle's choice of handling treatments in a Y-maze. Appl. Anim. Behav. Sci. 80, 93–107.
Prescott, N.B., Mottram, T.T., Webster, A.J.F., 1998. Relative motivations of dairy cows to be milked or fed in a Y-maze and an automatic milking system. Appl. Anim. Behav. Sci. 57, 23–33.