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Short communication: Lameness impairs feeding behavior of dairy cows

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ABSTRACT

The automated, reliable, and early detection of lameness is an important aim for the future development of modern dairy operations. One promising indicator of lameness is a change in the feeding behavior of a cow. In this study, the associations between feeding behavior and lameness were evaluated. A herd of 50 cows was investigated during the winter season in a freestall barn. Feeding behavior, feed intake, milk yield, and body weight were monitored using electronic feeding troughs and an automated milking system. Gait scoring every second week was used as a measure of lameness. To analyze the effect of lameness on feeding behavior and milk yield, linear mixed models were used. Cows with more severe lameness spent less time feeding per day (104 ± 4 , 101 ± 4 , and 91 ± 4 min/d for lameness scores 2, 3, and 4, respectively). An interaction between parity and lameness score was detected, with severely lame primiparous cows spending the least time feeding. Severely lame cows fed faster; however, their body weights were lower than for less-lame cows. Increase in lactation stage was associated with longer daily feeding time, longer duration of feeding bouts, and lower feeding rate. Worsening of gait was associated with lower silage intake and less time spent feeding even before severe lameness was scored. The results indicate that lameness is associated with changes in feeding behavior and that such changes could be considered in the future development of remote monitoring systems. It should also be noted that impaired feeding behavior along with lameness can put the welfare of especially early lactating primiparous cows at risk.

Key words: animal welfare, body weight, eating behavior, locomotion score

Short Communication

Lameness is common among dairy cows (Espejo et al., 2006) and often causes them pain (Whay et al., 1997). Lameness thus reduces the welfare of a large number of individual animals. Furthermore, lameness is associated with economic losses in dairy operations due to reduced milk yields (Green et al., 2002) and indirect costs that result from higher culling rates. Due to the lack of adequate monitoring, lame cows often go unrecognized (Whay et al., 2003; Espejo et al., 2006). Therefore, new approaches to detect lame cows on farms are needed. Despite recent research efforts (Potterton et al., 2012), the number of lame animals is not decreasing. Easier acquisition of data using new methodology that is applicable to large numbers of animals, together with increased knowledge about the etiology of lameness or recovery from it, will facilitate the understanding, prevention, and cure of the disease. At present, more information is also needed about behavioral adaptations and their associations with the development of lameness.

Changes in behavior may be indicative of poor health in animals (Weary et al., 2009). The connections between dairy cattle behavior and gait score have been studied, especially with regard to lying behavior (Gomez and Cook, 2010; Ito et al., 2010; Blackie et al., 2011). Despite serious attempts to use it as an indicator of lameness, lying behavior is proving to be too variable for providing a reliable measure (Ito et al., 2009; Ito et al., 2010; Yunta et al., 2012). In previous studies, changes in feeding behavior have successfully been used to detect other diseases, such as metritis (Urton et al., 2005; Huzzey et al., 2007; Goldhawk et al., 2009). However, few studies have focused on the aspects of feeding behavior as potential indicators of lameness.

Lower BCS (Espejo et al., 2006; Dippel et al., 2009) and decreased BW (Alawneh et al., 2012) have been found in lame cows. Onyiro et al. (2008) reported lower body weights to be associated with the stages of later lactation in lame cows and Alawneh et al. (2012) suggested that measurements of BW could aid in the detection of lameness. González et al. (2008) proposed

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daily feeding duration as the most promising behavioral measure for lameness detection due to its relatively low variability. Indeed, lame cows have been found to spend less time grazing on pasture (Hassall et al., 1993) and reduced feeding behavior and feed intake both seem to be associated with lameness (Bach et al., 2007; González et al., 2008; Palmer et al., 2012). Such changes in feeding behavior have been investigated with regard to lameness detection (Kramer et al., 2009; Yunta et al., 2012). Kramer et al. (2009), however, were not able to model lameness due to large variation between cows, and Yunta et al. (2012) only deduced shorter feeding duration based on observations of standing behavior around feed delivery time. Therefore, more research needs to be carried out to evaluate the suitability of different aspects of feeding behavior as lameness indicators. Several studies have focused on comparing the behavior of lame cows with that of sound animals, instead of investigating early changes in behavior that may be indicative of lameness. Therefore, we attempted also to investigate the association between behavior and lameness before a change in lameness was in effect recorded.

Aim

This study evaluated the relationship between locomotion scores on feeding behavior, feed consumption, and milk yield of dairy cows. We also examined early changes in feeding behavior to detect lameness and hypothesized that changes in feeding behavior could serve as early signs of the development of lameness.

Housing and Animals

The experiment was conducted at the University of Helsinki (Helsinki, Finland) during the winter season in an insulated loose house with freestalls and an automatic milking system. Cows were housed in a group of about 50 animals and milked with a milking robot (Astronaut A3; Lely Holding S.à r.l., Maassluis, the Netherlands). The cows were fed concentrates (0 to 19 kg/d) from the milking station and from 2 automatic feeders (Cosmix; Lely Holding S.à r.l.) according to their milk production. They were fed grass silage ad libitum from 22 automatic feeding troughs. The cows had free access to all feed troughs. Silage was delivered 4 times per day and orts were removed once per day. The silage was produced from mixed meadow fescue and timothy ensiled with formic acid. The silage contained, on average, 28% DM, with 15% CP and 53% NDF on a DM basis. The commercial concentrate (Rehuraíso, Raisio, Finland) contained, on average, 87% DM, with 22% CP and 13 MJ of ME/kg of energy. Water was offered ad libitum.

The barn comprised 2 rows of stalls and 2 alleys of 35 m length. The cows had access to 45 stalls with sawdust-bedded rubber mattresses, and the feeding alley had a solid rubber floor. Data were gathered from a total of 17 primiparous and 53 multiparous (parity range 2 to 6) cows. The predominant breed was Ayrshire, but the examined group also included 3 Holsteins, 2 Brown Swiss, 1 Jersey, and 1 Finncattle. The cows were, on average, 137 DIM (SD = 87 DIM) during the experiment.

Measurements

The data were gathered for 220 d. Consumption of silage and feeding behavior were measured from roughage feeding troughs equipped with electronic gates for discrete access and data recording for each individual cow (RIC; Insentec BV, Marknesse, the Netherlands). Total daily silage consumption (kg/d) of individual cows was the summation of silage consumed during all feeding bouts for each 24-h period. The duration of feeding of individual cows was registered automatically as the occupancy in roughage feeding troughs. The beginning and end of a feeding bout were recorded when a cow put her head through the gate and when she withdrew. Only feeding bouts that were longer than 1 min were included in the final data. The milking robot registered visits, milk yield, and BW.

As a measure of lameness, the cows were gait scored 15 times at intervals of approximately every 15 d (SD = 5 d; range = 10 to 28 d) by 2 observers according to Winckler and Willen (2001). The scoring took place while each cow was encouraged to walk on a rubber alley of the loose house. A scale of 5 levels was used, where score 1 = normal gait, 2 = uneven gait, 3 = short striding gait with 1 leg, 4 = short striding gait in more than 1 leg or strong reluctance to bear weight on 1 leg, and 5 = does not support 1 leg. If the scores given by the observers differed, their average was used in the analysis. The agreement between the observers was 95%. A gait score of 2 or lower was assigned at least once to 17 primiparous and 48 multiparous cows, a score of 3 was recorded for 13 primiparous and 34 multiparous cows, and a score of 4 or higher was found for 3 primiparous and 16 multiparous cows.

Statistical Analysis

To analyze the effect of lameness on feeding behavior (total daily feeding time, length of feeding bout, feeding rate, and silage intake), milk yield, milking frequency, and BW, linear mixed models were used. For the analysis, 10-d averages of daily results were calculated. Because of the rareness of lameness scores 1 and 5, these scores were merged with scores 2 and 4,

respectively. Time (10-d periods) and cow were used as random effects in the repeated statement. Days in milk (continuous measure), parity (primiparous and multiparous), lameness score, and interaction between parity and lameness were treated as fixed effects. The heterogeneous first-order autoregressive covariance structure provided the best model fit for the repeated measure.

For analyzing the effects of an increase in gait score on behavior and milk yield, linear mixed models were used. Data from all time periods between gait observations when an increase from score 3 to 4 or higher occurred, from all time periods when an increase from score 2 to 3 occurred, and data from all time periods when no increase or recoveries occurred were averaged. Total daily feeding time, length of feeding bout, feeding rate, silage intake, milk yield, milking frequency, and change in BW were analyzed. An increase in the lameness score was treated as a fixed factor with 3 levels, and cows were considered as random factors. The PASW statistical package (version 18.0.2; IBM Corp., Armonk, NY) was used for the analysis.

Associations with Lameness Scores

Feeding rates increased with higher lameness scores, whereas total silage feeding time per day decreased, especially in severely lame primiparous cows (Table 1). Declining time spend feeding by increased lameness is in agreement with the results of Bach et al. (2007), González et al. (2008), and Palmer et al. (2012). Despite faster feeding rates, severely lame cows had lower BW (Table 1), which is in agreement with Alawneh et al. (2012). In general, older cows that are closer to expected calving are the heaviest, and this trend can often conceal weight loss that could be associated with lameness. Weight loss may lead to thinning of the digital cushion of the claw (Bicalho et al., 2009), a condition associated with lameness.

The cows were presumably affected by competition for feed, as there were fewer silage feeders than cows in the overstocked barn. Competition for feed has previously been reported to increase aggressive interactions (DeVries et al., 2004), as well as to reduce feeding time and feed intake (DeVries and von Keyserlingk, 2009; Collings et al., 2011). It has also been reported to have disadvantageous effects on younger, smaller, newly calved, and high-yielding cows (Katainen et al., 2005; Val-Laillet et al., 2008; Huzzey et al., 2012). Feeding rate can be interpreted as an indicator of social pressure among group members (Nielsen, 1999; Collings et al., 2011), which suggests that competition had an adverse effect on lame primiparous cows in the current study. Moreover, to avoid confrontation with herd

Table 1. Average feeding behavior and milk yield of dairy cows as affected by lameness score and parity (n = 66; mean ± SE)

Item	Parity			Lameness score					P-value		
	Primiparous	Multiparous	1 and 2	3	4 and 5	Parity	Lameness	Interaction			
Feeding duration, min/d	95 ± 6	102 ± 4	104 ± 4 ^a	101 ± 4 ^b	91 ± 4 ^c	NS	0.001	0.037			
Feeding bout duration, min	5.5 ± 0.4 ^a	6.6 ± 0.2 ^b	6.2 ± 0.2	6.1 ± 0.2	5.9 ± 0.3	0.006	NS	NS			
Silage intake, kg/cow per day	24 ± 0.9 ^a	30 ± 0.5 ^b	28 ± 0.5	28 ± 0.5	26 ± 0.8	0.001	NS	NS			
Feeding rate, kg/min	0.160 ± 0.008	0.174 ± 0.005	0.159 ± 0.004 ^a	0.165 ± 0.005 ^b	0.177 ± 0.007 ^c	NS	0.001	NS			
Milk yield, kg/cow per day	31.0 ± 1.1 ^a	40.7 ± 0.6 ^b	35.9 ± 0.6	36.3 ± 0.6	35.3 ± 1.0	0.001	NS	NS			
Milking frequency/d	2.4 ± 0.09 ^a	2.9 ± 0.05 ^b	2.7 ± 0.04	2.7 ± 0.05	2.6 ± 0.09	0.001	NS	NS			
Weight, kg	688 ± 12 ^a	744 ± 8 ^b	718 ± 7 ^a	717 ± 7 ^a	713 ± 7 ^b	0.001	0.045	0.029			

^{a-c}Values within a row with different superscript letters are different ($P < 0.05$).

Table 2. Average feeding behavior, milk yield, milking frequency, and change in BW per cow as affected by an increase in lameness score from 2 or 3, or when no increase occurred ($n = 64$; mean \pm SE)

Item	No increase	Increase from 2 to 3 or higher	Increase from 3 to 4 or higher	<i>P</i> -value
Feeding duration, min/d	158 \pm 4 ^a	160 \pm 5 ^a	143 \pm 6 ^b	0.003
Feeding bout duration, min	7.4 \pm 0.3	7.5 \pm 0.3	7.3 \pm 0.4	NS
Silage intake, kg/cow per day	41 \pm 1 ^a	41 \pm 1 ^a	36 \pm 2 ^b	0.003
Feeding rate, kg/min	0.269 \pm 0.008	0.269 \pm 0.008	0.266 \pm 0.011	NS
Milk yield, kg/cow per day	39 \pm 18	38 \pm 18	39 \pm 19	NS
Milking frequency/d	2.8 \pm 0.1	2.9 \pm 0.1	2.8 \pm 0.2	NS
Change in BW, kg	4.1 \pm 0.9	3.6 \pm 1.1	4.1 \pm 2.2	NS

^{a,b}Values within a row with different superscript letters are different ($P < 0.05$).

mates and to reduce any pain caused by standing in the alley during feeding, lame cows may have fed faster. Higher feeding rates of lame animals may also be an attempt by prey animals to hide in the more remote resting areas as a manifestation of sickness behavior. In other studies, lame cows have been observed to use stalls more often (Proudfoot et al. 2010) and to rest more (Gomez and Cook, 2010; Ito et al., 2010; Blackie et al., 2011).

Increased DIM was associated with longer time spent feeding ($P = 0.008$; slope = 7.2 min/100 d; CI = 2.0 to 12.7), longer duration of feeding bouts ($P = 0.001$; slope = 0.6 min/100 d; CI = 0.3 to 0.9), and slower feeding rate ($P = 0.001$; slope = -29 g/min per 100 days, CI = -35 to -22). Milk yield decreased, whereas DIM increased ($P = 0.001$; slope = -3.1 kg/100 d; CI = -4.2 to -2.0).

In the current study, all cows in early lactation spent less time feeding, had shorter feeding bouts, and fed at a faster rate. Palmer et al. (2012) found a decrease in the DMI of lame cows during early lactation. The results of the present study and those reported by Palmer et al. (2012) suggest that lame cows in the most vulnerable phases of their lives (primiparous and early lactating) and during the highest need for energy seem to be affected in their feeding behavior. High yields, stage of early lactation, and young age can all strain the adaptive capacities of dairy cows and possibly predispose them to lameness. High milk yield increases the time spent standing in the short-term (Norrning et al., 2012), and even high production potential can predispose cows to lameness (Green et al., 2002). Whether reducing the demand for energy in primiparous or high-yielding cows affects their susceptibility to lameness remains an open question that could be experimentally addressed by inseminating heifers at an older age or by extracting less milk from cows, which is the approach used by Carbonneau et al. (2012).

Multiparous cows had longer feeding bouts, had higher feed intakes, produced more milk, and were milked more frequently. Despite the fact that the higher-yielding cows in our study were fed more con-

centrates than the lower-yielding cows, the older cows nonetheless consumed more roughage feed and the effect of lameness on silage feeding did not get masked.

Increase in Lameness Score

Silage intake and total feeding duration were lower in the 2-wk periods before further deterioration of the gait in animals that had previously been scored as lame (score 3). No such change was evident when cows developed less severe lameness only; the gait remained unaltered or the animals recovered (Table 2).

This indicates that reduced feed intake and decrease in time spent feeding might emerge simultaneously or even before a change in gait is visible in animals that are already lame. Changes in feed intake and total feeding duration may, therefore, serve as key signs in a cascade of behavioral changes associated with severe lameness, which can be used for the benefit of engineering better monitoring systems. In general, automated lameness detection systems are difficult to develop, possibly because of great variation in the symptoms that lame cows exhibit. Indeed, to be successful, such system needs to combine more than 1 sign associated with lameness (Chapinal et al., 2010). Lameness detection has been studied using acceleration, pressure platforms, and visual imaging as sources of information (Pastell et al., 2010; Chapinal et al., 2011; Viazzi et al., 2013). However, the technology of feeders and milking stations that are already used in modern cow houses could be integrated with these systems to provide robust and viable on-farm monitoring.

In conclusion, lameness seemed to impair the feeding behavior of especially primiparous cows. Variation in different aspects of feeding behavior deserves further attention in the future development of monitoring systems for lameness, especially in automated loose houses.

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REFERENCES

- Alawneh, J. I., M. A. Stevenson, N. B. Williamson, N. Lopez-Villalobos, and T. Otley. 2012. The effect of clinical lameness on liveweight in a seasonally calving, pasture-fed dairy herd. *J. Dairy Sci.* 95:663–669.
- Bach, A., M. Dinarés, M. Devant, and X. Carré. 2007. Associations between lameness and production, feeding and milking attendance of Holstein cows milked with an automatic milking system. *J. Dairy Res.* 74:40–46.
- Bicalho, R. C., V. S. Machado, and L. S. Caixeta. 2009. Lameness in dairy cattle: A debilitating disease or a disease of debilitated cattle? A cross-sectional study of lameness prevalence and thickness of the digital cushion. *J. Dairy Sci.* 92:3175–3184.
- Blackie, N., J. Amory, E. Bleach, and J. Scaife. 2011. The effect of lameness on lying behaviour of zero grazed Holstein dairy cattle. *Appl. Anim. Behav. Sci.* 134:85–91.
- Carbonneau, E., A. M. de Passillé, J. Rushen, B. G. Talbot, and P. Lacasse. 2012. The effect of incomplete milking or nursing on milk production, blood metabolites, and immune functions of dairy cows. *J. Dairy Sci.* 95:6503–6512.
- Chapinal, N., A. M. de Passillé, M. Pastell, L. Hänninen, L. Munksgaard, and J. Rushen. 2011. Measurement of acceleration while walking as an automated method for gait assessment in dairy cattle. *J. Dairy Sci.* 94:2895–2901.
- Chapinal, N., A. M. de Passillé, J. Rushen, and S. Wagner. 2010. Automated methods for detecting lameness and measuring analgesia in dairy cattle. *J. Dairy Sci.* 93:2007–2013.
- Collings, L. K. M., D. M. Weary, N. Chapinal, and M. A. G. von Keyserlingk. 2011. Temporal feed restriction and overstocking increase competition for feed by dairy cattle. *J. Dairy Sci.* 94:5480–5486.
- DeVries, T. J., and M. A. G. von Keyserlingk. 2009. Competition for feed affects the feeding behavior of growing dairy heifers. *J. Dairy Sci.* 92:3922–3929.
- DeVries, T. J., M. A. G. von Keyserlingk, and D. M. Weary. 2004. Effect of feeding space on the inter-cow distance, aggression, and feeding behavior of free-stall housed lactating dairy cows. *J. Dairy Sci.* 87:1432–1438.
- Dippel, S., M. Dolezal, C. Brenninkmeyer, J. Brinkmann, S. March, U. Knierim, and C. Winckler. 2009. Risk factors for lameness in free-stall housed dairy cows across two breeds, farming systems and countries. *J. Dairy Sci.* 92:5476–5486.
- Espejo, L. A., M. I. Endres, and J. A. Salfer. 2006. Prevalence of lameness in high-producing Holstein cows housed in freestall barns in Minnesota. *J. Dairy Sci.* 89:3052–3058.
- Goldhawk, C., N. Chapinal, D. M. Veira, D. M. Weary, and M. A. G. von Keyserlingk. 2009. Parturition feeding behavior is an early indicator of subclinical ketosis. *J. Dairy Sci.* 92:4971–4977.
- Gomez, A., and N. B. Cook. 2010. Time budgets of lactating dairy cattle in commercial freestall herds. *J. Dairy Sci.* 93:5772–5781.
- González, L. A., B. J. Tolkamp, M. P. Coffey, A. Ferret, and I. Kyriazakis. 2008. Changes in feeding behavior as possible indicators for the automatic monitoring of health disorders in dairy cows. *J. Dairy Sci.* 91:1017–1028.
- Green, L. E., V. J. Hedges, Y. H. Schukken, R. W. Blowey, and A. J. Packington. 2002. The impact of clinical lameness on the milk yield of dairy cows. *J. Dairy Sci.* 85:2250–2256.
- Hassall, S. A., W. R. Ward, and R. D. Murray. 1993. Effects of lameness on the behaviour of cows during the summer. *Vet. Rec.* 132:578–580.
- Huzzey, J. M., R. J. Grant, and T. R. Overton. 2012. Relationship between competitive success during displacements at an overstocked feed bunk and measures of physiology and behavior in Holstein dairy cattle. *J. Dairy Sci.* 95:4434–4441.
- Huzzey, J. M., D. M. Viera, D. M. Weary, and M. A. G. Von Keyserlingk. 2007. Parturition behavior and dry matter intake identify dairy cows at risk for metritis. *J. Dairy Sci.* 90:3220–3233.
- Ito, K., M. A. G. von Keyserlingk, S. J. LeBlanc, and D. M. Weary. 2010. Lying behavior as an indicator of lameness in dairy cows. *J. Dairy Sci.* 93:3553–3560.
- Ito, K., D. M. Weary, and M. A. G. von Keyserlingk. 2009. Lying behavior: Assessing within- and between-herd variation in free-stall housed dairy cows. *J. Dairy Sci.* 92:4412–4420.
- Katainen, A., M. Norring, E. Manninen, J. Laine, T. Orava, K. Kuoppala, and H. Saloniemi. 2005. Competitive behaviour of dairy cows at concentrate self-feeder. *Acta Agric. Scand. A Anim. Sci.* 55:98–105.
- Kramer, E., D. Cavero, E. Stamer, and J. Krieter. 2009. Mastitis and lameness detection in dairy cows by application of fuzzy logic. *Livest. Sci.* 125:92–96.
- Nielsen, B. L. 1999. On the interpretation of feeding behaviour measures and the use of feeding rate as an indicator of social constraint. *Appl. Anim. Behav. Sci.* 63:79–91.
- Norring, M., A. Valros, and L. Munksgaard. 2012. Milk yield affects time budget of dairy cows in tie-stalls. *J. Dairy Sci.* 95:102–108.
- Onyiro, O. M., J. Offer, and S. Brotherstone. 2008. Risk factors and milk yield losses associated with lameness in Holstein-Friesian dairy cattle. *Animal* 2:1230–1237.
- Palmer, M. A., R. Law, and N. E. O'Connell. 2012. Relationships between lameness and feeding behavior in cubicle-housed Holstein-Friesian dairy cows. *Appl. Anim. Behav. Sci.* 140:121–127.
- Pastell, M., L. Hänninen, A. M. de Passillé, and J. Rushen. 2010. Measures of weight distribution of dairy cows to detect lameness and the presence of hoof lesions. *J. Dairy Sci.* 93:954–960.
- Potterton, S. L., N. J. Bell, H. R. Whay, E. A. Berry, O. C. D. Atkinson, R. S. Dean, D. C. J. Main, and J. N. Huxley. 2012. A descriptive review of the peer and non-peer reviewed literature on the treatment and prevention of foot lameness in cattle published between 2000 and 2011. *Vet. J.* 193:612–616.
- Proudfoot, K. L., D. M. Weary, and M. A. G. von Keyserlingk. 2010. Behavior during transition differs for cows diagnosed with claw horn lesions in mid lactation. *J. Dairy Sci.* 93:3970–3978.
- Urton, G., M. A. G. von Keyserlingk, and D. M. Weary. 2005. Feeding behavior identifies dairy cows at risk for metritis. *J. Dairy Sci.* 88:2843–2849.
- Val-Laillet, D., A. M. de Passillé, J. Rushen, and M. A. G. von Keyserlingk. 2008. The concept of social dominance and the social distribution of feeding-related displacements between cows. *Appl. Anim. Behav. Sci.* 111:158–172.
- Viazzi, S., C. Bahr, A. Schlageter-Tello, T. Van Hertem, C. E. B. Romanini, A. Pluk, I. Halachmi, C. Lokhorst, and D. Berckmans. 2013. Analysis of individual classification of lameness using automatic measurement of back posture in dairy cattle. *J. Dairy Sci.* 96:257–266.
- Weary, D. M., J. M. Huzzey, and M. A. G. von Keyserlingk. 2009. Board-Invited Review: Using behavior to predict and identify ill health in animals. *J. Anim. Sci.* 87:770–777.
- Whay, H. R., D. C. J. Main, L. E. Green, and A. J. F. Webster. 2003. Assessment of the welfare of dairy cattle using animal-based measurements: Direct observations and investigation of farm records. *Vet. Rec.* 153:197–202.
- Whay, H. R., A. E. Waterman, and A. J. F. Webster. 1997. Associations between locomotion, claw lesions and nociceptive threshold in dairy heifers during the peri-partum period. *Vet. J.* 154:155–161.
- Winckler, C., and S. Willen. 2001. The reliability and repeatability of a lameness scoring system for use as an indicator of welfare in dairy cattle. *Acta Agric. Scand. A Anim. Sci.* 51:103–107.
- Yunta, C., I. Guasch, and A. Bach. 2012. Short communication: Lying behavior of lactating dairy cows is influenced by lameness especially around feeding time. *J. Dairy Sci.* 95:6546–6549.