LAMENESS CASES IN CATTLE REPORTED TO THE UNIVERSITY VETERINARY HOSPITAL, UNIVERSITI PUTRA MALAYSIA FROM 2013 TO 2017

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SUMMARY

This study was designed to characterise the lameness cases in cattle reported to the University Veterinary Hospital (UVH) of Universiti Putra Malaysia (UPM), Serdang, Selangor. Medical records from 2013 to 2017 were reviewed and 136 cases of cattle diagnosed as lameness were retrieved. Information concerning signalment, location of lesions, and cause of lameness was analysed. Majority of the cases were reported in dairy (77%) compared with beef cattle (23%) with 73% being under semi-intensive management system. Foot lesions accounted for about 51% of cases, while lesions were more on the hindlimbs than the forelimbs ($p<0.05$). The most common diagnoses were trauma related causes and there was no significant difference ($p>0.05$) between foot lesions categorised either as infectious or non-infectious causes. A higher proportion ($p<0.05$) of the cases were weight-bearing rather than non-weight bearing lameness, thus suggesting mild to moderate lameness. The findings suggest that routine claw trimming may be necessary to improve weight-bearing balance as majority of the foot lesions were present on the hindlimbs. The findings depict that lameness remains a major health issue in dairy herds and information herein may assist practitioners in addressing such painful condition.

Keywords: lameness, cattle, dairy, trauma, hindlimbs, foot lesions

INTRODUCTION

Lameness is a clinical manifestation of painful disorders in the form of impaired mobility, abnormal gait and posture, mostly connected to problems in the locomotor system (Van Nuffel *et al*. 2015). The estimated prevalence of lameness in cattle ranged from 0-60%, as well as incidence rate as high as 65 cases per 100 cow-years (Solano *et al*., 2015; Whay and Shearer, 2017). The wide range of this estimate indicated variation in number of factors influencing the occurrence, which include housing, nutrition, environment, seasonality, lameness detection methods, and purpose of production (Ranjbar *et al*., 2016).

Lameness remains an important welfare problem and production limiting condition in the dairy industry. A crucial issue amongst farmers is the under-estimation of lameness prevalence in their herds as well as inadequate knowledge for optimum vigilance and detection (Gundelach *et al*. 2013). Hence, events such as chronicity and unsuccessful treatment contribute to the sub-optimal welfare in lame cows (Thomas *et al*., 2016), leading to economic losses such as early culling (Randall *et al*., 2016), poor reproductive performance (Gomez *et al*., 2015), and reduced milk yield (Charfeddine and Perez-Cabal, 2017). Nevertheless, lameness has been shown to be important in beef cattle. For instance, lameness prevalence of 26.6% and 36.3% was reported in cows and bulls (beef animals) at parking plants (Roeber *et al.*, 2001). Also, a seven year record (2005-2012) found 745 cases of lameness in beef cattle reported to an institutions' animal teaching hospital in the United States (Newcomer and Chamorro, 2016).

Claw lesions are regarded as the main causes of bovine lameness (Manske *et al*. 2002). Claw lesions could either be infectious or non-infectious, in which the former include lesions arising from pathological changes attributed to infection of the digital skin (Potterton *et al*. 2012). Hence, they are referred to as foot skin lesions with digital dermatitis, heel horn erosion, and foot rot being predominant. Non-infectious causes also referred to as laminitis or claw horn lesions are manifestations of pathological changes within the claw capsule and sequels to sole ulcer and white line disease (van Amstel and Shearer, 2006). Generally, laminitis is used to describe a systemic condition that affects the overall condition of the animal and not only the foot. Studies have indicated that the inflammation is connected to malfunction of the digital vasculatures, leading to hypoxia and perfusion of the sensitive laminar within the claw capsule (Greenough, 2009). These events are often linked to metabolic and hormonal processes occuriring around calving that weakens the stability of the claw bone and suspensory apparatus (Tarlton *et al*., 2002; Newsome *et al*., 2017) couple with biomechanical reaction between the claw and hard flooring (Bergsten *et al*., 2015). Low body condition score, thinning of the digital cushion (Bicalho *et al*., 2009) and overgrown claw (Solano *et al*., 2015; Sadiq *et al*., 2017a) are also important cow level risk factors. Other claw lesions regarded as non-infectious include sole haemorrhage, double soles, vertical fissure and horizontal fissure, toe necrosis, thin sole, toe ulcers and under-running of the heels (Bergsten *et al*., 2009). Lameness can also result from traumatic injuries, which include pedal bone fractures and penetration by foreign bodies, thus leading to septic arthritis or septic tenosynovitis (Greenough, 2009).

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Studies related to bovine lameness are relatively scarce in Selangor, Malaysia. However, a recent study reported cow level prevalence of clinical lameness and claw lesions of 19% and 33% respectively amongst selected dairy farms in the state (Sadiq *et al*., 2017a). However, there is paucity of information on relative distribution of lesions causing lameness in beef cattle, while more published data is still required to gain knowledge on the same problem in dairy herds in the region. A study by Abdullah *et al*. (2017) showed that selected dairy cattle farmers in the region had low compliance to herd health program. In order to solve issues related to low productivity among ruminant farmers, the Faculty of Veterinary Medicine, Universiti Putra Malaysia introduced an initiative known as "Program Ladang Angkat" in September, 2011. Over time, cases of lameness have been reported from these farms to UVH. Information therein could be plausible in understanding the relative prevalence of lameness in cattle, lesions distribution, and management risk factors. Hence, the aim of this study was to describe the occurrence of lameness cases reported to the UVH from 2013 to 2017.

MATERIALS AND METHODS

The records of all lameness cases presented to the UVH from January 1, 2013 to December 31, 2017 were assessed for complaint of lameness either in dairy or beef cattle, request for claw trimming, or lameness as the final diagnosis. The ruminant caseload consisted of entries of cases related to both caprine, ovine and bovine species. Data were screened for cattle and relevant information was noted, such as date of first visit, animal ID, location of farm and management practices. Data collected on signalment included age, breed, sex, weight, limbs affected, distribution and site of lesion (e.g., hoof, tarsus, stifle), treatment, date of the next visit, and outcome of treatment or management plans if any. If applicable, the claw affected (lateral or medial) were also noted. Within this period of time, a total of 136 cases of lameness in cattle were identified and recorded.

The data were tabulated in Microsoft Excel (2016) spread sheet, while the IBM SPSS Statistics for Windows Version 24.0, (Armonk, N.Y., USA: IBM) was used for all statistical analysis. Binomial test based on an expected proportion of 0.5 was used to compare the difference between two binomial proportions outcome. Other variables with more than two categories were analysed using cross tabulation and reported in frequency distribution.

RESULTS

Descriptive and characteristics of lameness cases

A total of 136 (mean ± standard deviation; 27.2 ± 7.8) lameness cases were reported to UVH within the 5 year period with the highest number of cases recorded in 2017 (Figure 1).

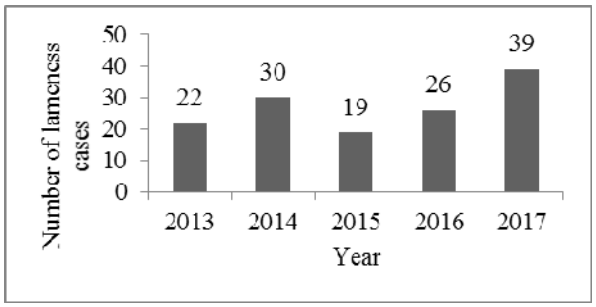

Figure 1. Yearly distribution of lameness cases reported to UVH from 2013 to 2017

The monthly distribution showed that the highest lameness cases were recorded in April and November, while the lowest was around the middle of the year (Figure 2). The characteristics of the lameness cases reported to the UVH from 2013 to 2017 is shown in Table 1. Majority of the cases ($p<0.05$) were reported from *Ladang Angkat* farms (88.2%) compared to walk-in clients (11.8%), while a higher proportion ($p<0.05$) engaged in semi-intensive management system (73.6%). Also, dairy cattle (77.2%) were mostly affected compared with beef cattle (22.8%). Other important findings included adult and female cattle being the most affected and majority of the lameness severity were weight bearing lameness (67.6%).

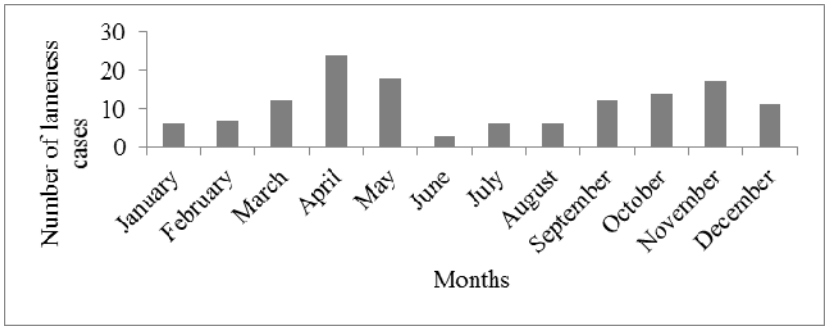

Figure 2. Monthly distribution of lameness cases reported to UVH from 2013-2017

Majority of the lesions or disorders causing lameness were recorded on the foot (50.6%), whereas other causes related to injuries present on the hock, metacarpus/carpus, stifle, metatarsus, humerus, fetlock and radius were less than 10% (Table 2). Subsequently, the foot lesions were categorised based on those affecting the digital skin and the claw horn. There was no significant difference in the proportion of foot lesions regarded as foot skin (44.4%) or claw horn lesions (55.6%) (Table 3). However, a significantly higher number of the foot lesions were present in the hindlimbs (63.2%) compared with the forelimbs (17%). A total of 29 cases were revisited and only 24.2% (n=7/29) showed improvement.

The clinical diagnosis of the lameness cases is presented in Table 4. Majority of the cases were attributed to trauma (48.4%), joint problems (17.5%), foot rot (9.5%), sole lesions (7.1%), and overgrown hoof (5.5%). In the treatment of lameness cases, the use of anti-inflammatory (65%), antibiotic therapy (48%), and wound dressing (40%) was common, while foot trimming was the least applied (6%) (Figure 3).

Table 1. Characteristics of lameness cases reported to the UVH from 2013 to 2017

Features	Number	%	P-value
Source			
Ladang Angkat	120	88.2	P<0.05
Walk-in clients	14	11.8	
Purpose			
Dairy	105	77.2	P<0.05
Beef	31	22.8	
Age group			
Young	19	13.9	P<0.05
Adult	117	86.1	
Sex			
Female	41	31.1	P<0.05
Male	95	69.9	
Management system			
Intensive	18	13.2[a]	P<0.05
Semi-intensive	100	73.6[b]	
N/A*	18	-	
Lameness severity			
Weight bearing	92	67.6[a]	P<0.05
Non-weight bearing	30	22.1[b]	
N/A*	24	-	

%, percentage; N/A*, not available (Excluded from the analysis); P-value <0.05 is significantly different; Values in the same column with different superscript[a,b] are significantly different.

Table 2. Site and frequency of the lesions causing lameness as reported to the UVH from 2013-2017

Site of lesion	Number of cases	Percentage (%)
Foot	76	50.6
Hock	10	6.6
Metacarpus/carpus	6	4.0
Stifle	6	4.0
Metatarsus	5	3.3
Humerus	4	2.6
Fetlock	3	2.0
Radius	2	1.3
Unknown	24	16.0
Mix[a]	14	9.3
Total	150	100.0
Median (range)	6 (74)	

[a] combination of lesions site excluding that of the foot

Table 3. Frequency distribution of foot lesions based on site, location on the limbs, and revisit cases

Features	Number of cases (%)	P-value
Lesions		
Foot skin[a]	55 (44.4)	P>0.05
Claw horn lesions[b]	69 (55.6)	
Location		
Hindlimb	86 (63.2)[c]	
Forelimb	23 (17.0)[d]	
Both	13 (9.5)[d]	
N/A	14 (10.3)[d]	
Revisit cases		
Improved gait	7 (24.2)	P <0.05
No improvement	22 (75.8)	

[a] lesions present on the skin and not affecting the claw horn tissue
[b] lesions present on the claw horn tissues, overgrown hoof and traumatic sole injuries
Comparison is within rows and values with different superscript are significantly different
Values in the same column with different superscript are significantly different
N/A = not available

DISCUSSION

This study revealed that the highest lameness cases were in 2017. However, little can be inferred from this finding as it could either depict increasing lameness cases in the farms or as a result of more frequent visits to the farms within the year leading to more reported lameness cases. Nevertheless, the weather could have played a role on the findings from this study as lameness cases varied by months. According to the official website of Malaysian Meteorology (http://www.met.gov.my, 18th February 2017) the primary maximum rainfall generally occur from October to November, while secondary maximum rainfall generally occur from April to May. The findings from this study seem to coincide with this weather patterns.

Table 4. Frequency of lameness cases based on clinical diagnosis

Lameness diagnosis	Number of cases	Percentage (%)
Traumatic injury	61	48.4
Joint problem[a]	22	17.5
Foot rot	12	9.5
Sole lesions	9	7.1
Fracture	6	4.8
Overgrown hoof	7	5.5
Suspected FMD	3	2.4
Sciatic nerve avulsion	1	0.8
N/A	5	3.9
Total	126	100.0
Median (range)	7(60)	

[a] conditions such as swollen coronet, hock swellings and septic arthritis; N/A = not available; FMD=foot and mouth disease

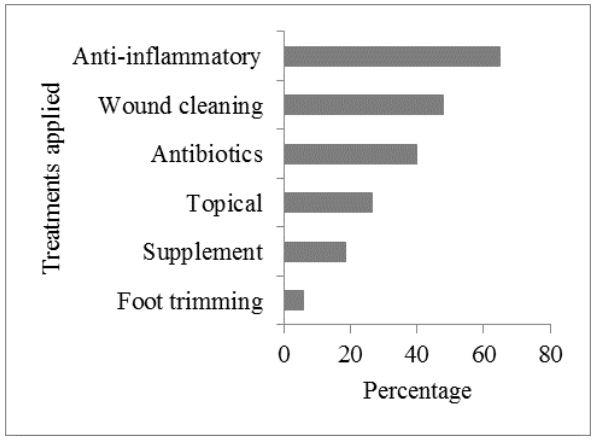

Figure 3. Distribution of treatment applied for lameness cases reported to UVH from 2013 to 2017

The result based on the source of reported cases as majority were from the *Ladang Angkat* farms was expected, since there was active scheduled farm visits. In the same context, a higher number of farms reporting lameness cases were managed semi-intensively. This event is not far-fetched since it still remains the most common practice in the Malaysian dairy industry **(**Mohd Karim *et al*., 2014). Similarly, previous studies in the region have shown that higher proportion of dairy farmers practice the aforementioned management system in Selangor (Abdullah *et al*., 2017; Sadiq *et al.*, 2017a). However, the system of confining cows either intensively or semi-intensively has been suggested to contribute to the rising lameness problems in dairy herds, especially, as cows are often selected for high production, housed with less access to external pasture, and prolonged standing times on uncomfortable surfaces (Cook *et al*., 2016; Ranjbar *et al*., 2016). This could also explain the higher proportion of lameness cases in dairy cattle as reported in the present study. The finding might be in accordance to greater population of dairy cows in the herds as well as them not regarding lameness as an important condition in beef cattle or male herd mates. These events are pertinent since production losses accorded to lameness are not often obvious in beef cattle and bulls compared with dairy cows producing milk. On the same note, more than half of the lameness cases were diagnosed as weight bearing. According to the lameness scoring system developed by Sprecher *et al*. (1997), non-weight bearing is a feature of severe cases of lameness. This implies that majority of the lameness cases reported herein ranged from mild to moderate, which might be attributed to the scheduled farm visits and assessment by trained personnel favouring the prompt detection of lame cows.

In the present study, foot lesions accounted for majority of the lameness cases. This finding is in agreement with the result of Sadiq *et al*. (2017a), when foot lesions accounted for about 85% of lameness cases in selected dairy farms in Selangor, Malaysia. Such conditions are often attributed to the continuous standing and walking on hard concrete flooring system as well as changes within the claw capsule at peri-calving periods (Bergsten *et al*., 2015). Particularly, the low awareness among dairy farmers in Selangor on important claw health management practices and low compliance to herd health programs might be contributing factors (Abdullah *et al*., 2017; Sadiq *et al*., 2017b).

According to Potterton *et al*. (2012), foot lesions affecting the digital skin or claw horn are referred to as infectious and non-infectious claw lesions, respectively. As found herein, the foot lesions based on the aforementioned categories were not different among the lameness cases. The similar proportion of cases might be attributed to various factors influencing the occurrence in the farms reporting lameness cases to the UVH. More studies are needed to investigate herd specific factors associated with lameness in the region. Again, majority of the lameness disorders were present in the hindlimbs compared with the forelimbs. Several studies have reported similar cases (Somers and O'Grady, 2015; Refaai *et al.,* 2017), which is considered to be influenced by the weight distribution of the cattle unto the rear region. The weight of the cow is mainly borne by the hindlimbs, especially the lateral compared to the medial claw. In contrast, weight distribution between the medial and lateral claws in the frontlimb is more equal (van Amstel and Shearer, 2006; Greenough, 2009). Although, claw trimming is often carried out in an attempt to improve the imbalance in the hind feet, still most of the weight is borne by the lateral claw (van Der Tol *et al*., 2004). Hence, the finding in this study reflected such uneven weight distribution based on the relative prevalence of foot lesions leading to hindlimb lameness. Moreover, a recent study indicated dairy farmers in Selangor rarely practice claw trimming (Sadiq *et al*., 2017b), which might further reduce claw health of dairy cows in various herds.

Majority of the cases were attributed to trauma and less of joint problems, footrot, sole lesions, and overgrown hoof. Accordingly, most of the foot lesions and hock injuries representing the leading causes of lameness in dairy herds have been attributed to trauma. These conditions arise from biomechanical reactions at floor-claw interface, inadequate stall designs,

inappropriate human handling, and slips/falls on slippery floor surfaces (Solano *et al*., 2015; Bouffard *et al*., 2017). However, other conditions affecting the joints (septic athritis) and infectious claw lesions like footrot are also painful conditions causing severe lameness in dairy cows (Greenough, 2009).

Treatment of lameness cases as found in records showed that the common use of anti-inflammatory, antibiotic therapy and wound dressing, whereas foot trimming was the least applied. These treatment measures are expected since the aim is to relieve pain in the affected cow, eliminate infectious agents if indicated, and provide the optimum condition for wound healing. However, the low application of foot trimming might be influenced by the availability of treatment facilities and expertise of personnel involved. Accordingly, appropriate claw trimming techniques is necessary to improve foot health, otherwise, more harm is done rather than good (Mahendran and Bell, 2015). In addition, only a few of the revisited cases showed improvement. This finding might be due to the treatment plans as majority of the cases were managed symptomatically. Another likely contributing factor is the severity of lameness with indications of most cattle being chronically affected, while the scheduled farm visits might limit the time allocated for treatment plans.

CONCLUSION

In summary, this report describes the distribution and relative prevalence of lameness cases in dairy cattle presented to UVH over a 4-year period. Majority of lameness cases were attributed to foot lesions with mostly occurring in the hind feet. Also, the stifle, metatarsus, carpus, fetlock, and shoulder are other few sites of lesions causing lameness proximal to the foot. Lameness was not different in terms of non-infectious or infectious aetiology. However, information was lacking for definitive diagnosis of specific claw lesions. Hence, more investigation is needed to arrive at the major foot lesions causing lameness in various herds managed under different systems. Lameness is a major welfare and economic issue in dairy herds and the data presented herein could help practitioners in the assessment of lameness and managing the painful condition.

CONFLICT OF INTEREST

The authors declare that they have no conflicting interest.

REFERENCES

Abdullah, F.F.J., Sadiq, M.A., Abba, Y., Ropie, A.M., Mohammed, K., Lim, E., Bitrus, A.A., Mat Isa, N.H., Mohd Lila, M.A., Haron, A. and Saharee, A.A. (2017). A cross-sectional study on the association between farmers' awareness and compliance on herd health programme among five selected dairy cattle farms in Selangor and Negeri Sembilan states, Malaysia. Malaysian Journal of Veterinary Research, 8(1): 19-29

Bergsten, C., Telezhenko, E. and Ventorp, M. (2009). Importance of soft and hard flooring system for claw conformation, locomotion, claw- and leg health in heifers and first calvers. In: XIV ISAH Conference 2009, Vechta

Bergsten, C., Telezhenko, E. and Ventorp, M. (2015). Influence of Soft or Hard Floors before and after First Calving on Dairy Heifer Locomotion, Claw and Leg Health, Animals (Basel), 5, 662-686

Bicalho, R.C., Machado, V.S. and Caixeta, L.S. (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, Journal of Dairy Science, 92, 3175-3184

Bouffard, V., de Passille, A.M., Rushen, J., Vasseur, E., Nash, C.G., Haley, D.B. and Pellerin, D. (2017). Effect of following recommendations for tiestall configuration on neck and leg lesions, lameness, cleanliness, and lying time in dairy cows. Journal of Dairy Science, 100, 2935-2943

Cook, N.B., Hess, J.P., Foy, M.R., Bennett, T.B. and Brotzman, R.L. (2016). Management characteristics, lameness, and body injuries of dairy cattle housed in high-performance dairy herds in Wisconsin. Journal of Dairy Science, 99: 5879-5891.

Charfeddine, N. and Perez-Cabal, M.A. (2017). Effect of claw disorders on milk production, fertility, and longevity, and their economic impact in Spanish Holstein cows, Journal of Dairy Science, 100, 653-665

Gundelach, Y., Schulz, T., Feldmann, M. and Hoedemaker, M. (2013). Effects of Increased Vigilance for Locomotion Disorders on Lameness and Production in Dairy Cows, Animals (Basel), 3, 951-961

Gomez, A., Cook, N.B., Rieman, J., Dunbar, K.A., Cooley, K.E., Socha, M.T. and Dopfer, D. (2015). The effect of digital dermatitis on hoof conformation, Journal of Dairy Science, 98, 927-936

Greenough, P.R. (2009). Animal welfare in dairy farming: Lameness and the organic movement, Veterinary Journal, 2, 180, 3-4

Mahendran, S. and Bell, N. (2015). Lameness in cattle 2. Managing claw health through appropriate trimming techniques, In Practice, 37:231-242

Manske, T., Hultgren, J. and Bergsten, C. (2002). Prevalence and interrelationships of hoof lesions and lameness in Swedish dairy cows, Preventive Veterinary Medicine, 54, 247-263

Mohd Karim, Z., Arumugam, N., Nguang, S.I., and Baba, A.R. (2014). Determinants for Sustainability in the Dairy Industry in Malaysia. In: National Postgraduate Symposium on Sustainable Agriculture, 2014

Newcomer, B.W. and Chamorro, M.F. (2016). Distribution of lameness lesions in beef cattle: A retrospective analysis of 745 cases, Canadian Veterinary Journal, 57, 401-406.

Potterton, S.L., Bell, N.J., Whay, H.R., Berry, E.A., Atkinson, O.C., Dean, R.S., Main, D.C. and Huxley, J.N. (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, Veterinary Journal, 193, 612-616

Ranjbar, S., Rabiee, A.R., Gunn, A. and House, J.K. (2016). Identifying risk factors associated with lameness in pasture-based dairy herds, Journal of Dairy Science, 99, 7495-7505

Randall, L.V., Green, M.J., Chagunda, M.G., Mason, C., Green, L.E., and Huxley, J.N. (2016). Lameness in dairy heifers; impacts of hoof lesions present around first calving on future lameness, milk yield and culling risk, Preventive Veterinary Medicine, 133, 52-63

Refaai, W., Gad, M. and Mahmmod, Y. (2017). Association of claw disorders with subclinical intramammary infections in Egyptian dairy cows. Veterinary World, 10(3): 358-362

Roeber, D.L., Mies, P.D., Smith, C.D., Belk, K.E., Field, T.G., Tatum, J.D., Scanga, J.A. and Smith, G.C. (2001). National market cow and bull beef quality audit-1999: a survey of producer-related defects in market cows and bulls, Journal of Animal Science, 79, 658-665

Sadiq, M.B., Ramanoon, S.Z., Mansor, R., Syed-Hussain, S.S. and Shaik Mossadeq, W.M. (2017a). Prevalence of lameness, claw lesions, and associated risk factors in dairy farms in Selangor, Malaysia, Tropical Animal Health and Production, 49, 1741-1748

Sadiq, M.B., Ramanoon, S.Z., Shaik Mossadeq, W.M., Mansor, R. and Syed-Hussain, S.S. (2017b). Association between Lameness and Indicators of Dairy Cow Welfare Based on Locomotion Scoring, Body and Hock Condition, Leg Hygiene and Lying Behavior, Animals (Basel), 7,

Solano, L., Barkema, H.W., Pajor, E.A., Mason, S., LeBlanc, S.J., Zaffino Heyerhoff, J.C., Nash, C.G., Haley, D.B., Vasseur, E., Pellerin, D., Rushen, J., de Passille, A.M. and Orsel, K. (2015). Prevalence of lameness and associated risk factors in Canadian

Holstein-Friesian cows housed in freestall barns, Journal of Dairy Science, 98, 6978-6991

Somers, J. and O'Grady, L. (2015). Foot lesions in lame cows on 10 dairy farms in Ireland, Irish Veterinary Journal, 68, 10

Sprecher, D.J., Hostetler, D.E. and Kaneene, J.B. (1997). A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. Theriogenology, 47: 1179-1187

Tarlton, J.F., Holah, D.E., Evans, K.M., Jones, S., Pearson, G.R. and Webster, A.J. (2002). Biomechanical and histopathological changes in the support structures of bovine hooves around the time of first calving, Veterinary Journal, 163, 196-204

Thomas, H.J., Remnant, J.G., Bollard, N.J., Burrows, A., Whay, H.R., Bell, N.J., Mason, C. and Huxley, J.N. (2016). Recovery of chronically lame dairy cows following treatment for claw horn lesions: a randomised controlled trial, Veterinary Record, 178, 116

van Amstel, S. and Shearer, J. (2006). Manual for Treatment and Control of Lameness in Cattle. Ames, Iowa: Blackwell, 2006.

van der Tol, P.P., Metz, J.H., Noordhuizen-Stassen, E.N., Back, W., Braam, C.R. and Weijs, W.A. (2005). Frictional forces required for unrestrained locomotion in dairy cattle. Journal of Dairy Science, 88, 615-624.

Van Nuffel, A., Zwertvaegher, I., Van Weyenberg, S., Pastell, M., Thorup, V.M., Bahr, C., Sonck, B. and Saeys, W. (2015). Lameness detection in dairy cows: part1. How to distinguish between non-lame and lame cows based on differences in locomotion or behavior, Animals, 5, 838-860

Whay, H.R. and Shearer, J.K. (2017). The Impact of Lameness on Welfare of the Dairy Cow, Veterinary Clinics of North American Food Animal Practice, 33, 153-164