Biomechanics of the bovine foot

Christoph K.W. Mülling

Institute of Veterinary Anatomy, Histology and Embryology, Faculty of Veterinary Medicine, Leipzig University, An den Tierkliniken 43, 04103 Leipzig/Germany; c.muelling@vetmed.uni-leipzig.de.

Lameness is one of the most important problems in modern dairy husbandry (Winckler and Brill, 2004; Barker et al. 2010; Hilger and Passarge, 2018), which is mainly caused by claw lesions (Mülling and Lischer, 2002) especially in the hind limbs (Knott et al., 2007). These claw lesions do not only cause considerable animal welfare problems but also generate economic losses due to decline of milk yield and fertility (Bicalho et al., 2008; Cha et al., 2010; Liang et al., 2017).

The bovine claw is the interface between the dairy cow and the environment. Anatomically, the claw is designed for stance and locomotion on pasture type ground and requires limited periods of standing. Standing and walking on hard floors and extended periods of standing inevitably lead to damage of the interior structures of the claw.

We have gained considerable insight in the impact of the cow's environment on claw structure and function. The impact of the environment is either directly mechanical, chemical or biological or indirectly by altering the cow's behavior and secondary causing damage to the claw tissues. Environmental factors, cow comfort and cow behavior are understood as key factors in the multifactorial etiology of claw diseases and in lameness prevention (Barker et al. 2009; Cook and Nordlund, 2009; Cook et al., 2004). Claw lesions are inevitably associated with indoor housing systems.

It is nowadays well established that non-infectious claw lesions, which develop subsequent to initial tissue alterations associated with claw horn disruption (CHD), have a multifactorial etiology. And they have a strong biomechanical component in their etiopathogenesis. It has been suggested more recently that mechanical influences and mechanically caused or initiated tissue alterations in the claw maybe the predominant or even exclusive cause for CHD lesions. The idea of a predominantly mechanical etiology is not new. In 1920 Anton Rusterholz published two articles on "the specific-traumatic sole ulcer in cattle" in the Swiss Archives for Veterinary Medicine (Schweizer Archiv für Tierheilkunde – SAT) (Rusterholz, 1920). He provided a detailed anatomical description of the ulcer, which was later on named after him. He also described the etiology and pathogenesis in depth and established a direct causal link between housing, namely hard floor, and the development of bone exostoses on the distal phalanx and subsequently ulcers (see figure 1).

Rusterholz also postulated a genetic component in the etiopathogenesis. Genetics nowadays receive rapidly growing attention in more recent research and genetics provide powerful opportunities to enhance claw health by genetic section (Heringstad et al., 2017).

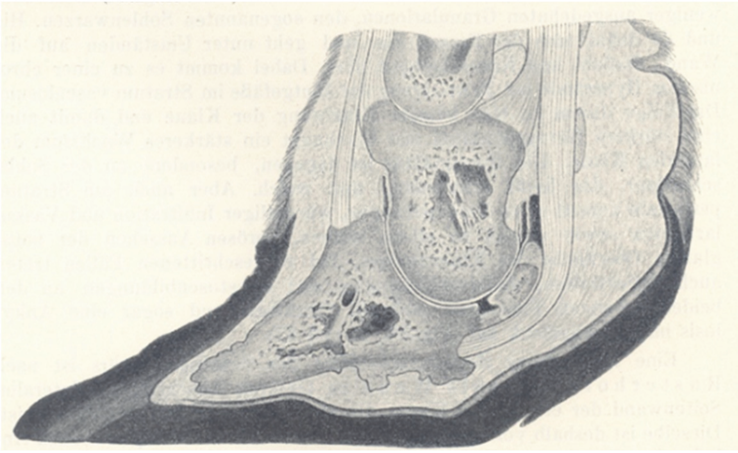


Figure 1. Left: Exostosis (bone development) on the distal phalanx due to pressure on hard floor, sinking of the rear part of the bone. Right: Sole Ulcer. (Rusterholz 1920).

In 1963 Nilson published his PhD thesis on clinical, morphological and experimental studies of laminitis in cattle (Nilson, 1963). For decades to follow our comprehension of what was called subclinical laminits (nowadays claw horn disruption - CHD) and the associated claw lesions and also our research focused on nutrition and metabolism. About 20 years ago we saw a paradigm shift. Our evidence based understanding of the etiopathogenesis of non-infectious claw lesions as a metabolic or primarily nutrition related problem changed to understanding it as an environment associated mechanical/pressure induced disease. Pioneering studies demonstrated that the strength of the suspensory apparatus was affected by housing in cubicles but not by nutrition (Tarlton et al., 2002; Knott et al., 2007). The structural integrity of connective tissue was most severely compromised by housing in cubicles (Tarlton et al., 2000; Webster et al., 2005). Parturition and lactation amplified this effect whereas feeding had no significant influence (Webster, 2001, 2003; Webster et al., 2005). The dermis is exposed to high local mechanical pressure (Hinterhofer et al., 2006; van der Tol, 2002), particularly when cows are standing for excessively long periods. Today much greater importance is attached to inadequate housing, foot care and parturition than to nutrition and feeding. Evidence has been generated that housing and claw trimming are a major hazard (Webster 2001, 2003).

Recent work by Newsome et al. (2015, 2016) has breathed new life into Rusterholz ideas and postulates from 100 year ago. Bone development (exostoses) on the caudal aspect of the distal phalanx have been linked with claw lesions and lameness (Newsome et al., 2015); chronic inflammatory changes in the bone initiated or caused by pressure are discussed. Evidence for the biomechanical etiopathogenesis is growing.

The distal phalanx inside the claw is suspended by a collagen fiber system inside the claw capsule the same time it is supported by a system of digital fat cushions acting as support and shock absorber during locomotion. The distal phalanx is fixed very tight in its position. The attachment by the suspensory apparatus only allows for a downward movement in the submillimeter scale preventing damaging pressure on the sensitive corium and living horn producing epidermis (Lischer et al., 2002; Maierl et al., 2002; Mülling and Lischer 2002; Newsome et al. 2017; Räber et al. 2004, 2006; Westerfeld et al., 2000, 2004). During the peri-parturition period and throughout the onset of lactation the properties of the connective tissue of the suspensory apparatus undergo changes leading to decreased stability of the collagen system of the dermis (Holah et al., 2002; Mülling et al., 2004). As a result, there is increased mobility of the distal phalanx inside the claw capsule (Lischer et al., 2002, Mülling and Lischer, 2002). Changes in position of the distal phalanx, i.e. sinking rotation and/or tilting to axial or abaxial) have been demonstrated in pathomorphological studies (Bergsten, 2003; Lischer et al., 2002; Mülling and Lischer, 2002). This will cause increased pressure onto the dermis and living epidermis (germinative layer) as the soft living tissues inside the claw are caught between a rock and a hard place.

We are still lacking information on what exactly happens inside the claw during standing/excessive standing times and during locomotion. What are influences of different floor systems/types? What is the correct or best possible approach to preventive trimming? What is the optimal trimming method? Understanding the claw-floor interaction and the precise influences of good and bad trimming on the interior structures of the claw provides the key to understand the pathogenesis of non-infectious claw lesions and to successful prevention of lesions. We therefore need an objective evaluation of floor systems and trimming to generate scientific evidence for what should be best practice.

Today, we have the methods and tools in biomechanical research to shed light on key events inside the claw and reveal mechanisms involved in the biomechanical pathogenesis of non-infectious lesions. Biomechanical research describes, examines and evaluates the locomotor system of biological systems by employing knowledge and methods from mechanics, anatomy and physiology. In the context of claw lesions and cattle lameness the general aims of biomechanical research are data acquisition of physiological motion and strain, analysis of locomotive patterns linked to pathologies and the analysis of different influences on motion, e.g. claw trimming, ground conditions. Within biomechanical research there are two main areas: kinetics and kinematics. Kinetical research is dedicated to the analysis of internal (muscle) and external (friction) locomotor forces. In the context of claw lesion development kinetic research focuses on claw trimming (Carvalho, 2004; van der Tol et al., 2004; Zeiner et al., 2007), ground conditions (deBelie et al., 2003; Franck et al., 2006), influence of age, race etc. (Huth et al., 2005; Nuss et al., 2015; Razak et al., 2012; Spielmann, 1984, van der Tol et al., 2002, 2003). Kinematic research is dedicated to the analysis of bodily motion in space in terms of position, velocity and acceleration. Methods of kinematic research include videocinematography (Feßl, 1974; Herlin et al., 1997; Meyer et al., 2006/2007; Schmid et al., 2008), optoelectronic systems (Blackie et al., 2013), biplane high-speed fluoroscopic kinematography (Weiß et al., 2017, 2019) and furthermore electrogoniometry, electromagnetic/ultrasonographic systems. Biplane high-speed fluoroscopy or XROMM is a relatively new method for three-dimensional analysis of bone motion with the promise of submillimeter and subdegree accuracy. It is a promising tool for gaining further insight into the claw floor interaction and for evaluation of trimming methods and flooring systems (Weiss et al., 2017, 2019).

Biomechanical research in cattle is frequently used to optimize, objectify and automatize lameness detection. The arsenal of methods includes pressure measurement (Pluk et al., 2012), force plates (Rajkondawar et al., 2006; Pastell et al., 2007; Bicalho et al., 2007; Ghotoorlar et al., 2012; Dunthorn et al., 2015), IMU/accelerometer/pedometer (Chapinal et al., 2011; Mangweth et al., 2012; Thorup et al., 2014; Alsaaod et al., 2017), videocinematography (Flower et al., 2005; Pluk et al., 2012; Van Hertem et al., 2013; Viazzi et al., 2013).

The development of technology and methods has focused on the use of sensors, force plates and accelerometers for lameness detection. Detection of lameness using objective standardized methods is an expanding field of research. More recent work includes the use of force sensors (Kujala et al., 2008), pressure plates (van der Tool et al., 2002, 2003, 2004) plates, and accelerometers (Chapinal et al., 2011; Mangweth et al., 2012; Thorup et al., 2014; Alsaaod et al., 2017). Very limited attention has been given to using the technologies available for biomechanical research on the claw floor interaction in cattle under field conditions. An advanced locomotion scoring systems measuring ground reaction forces and locomotion speed was used in a commercial farm setting (Walker et al., 2010). Systems available for research are too expansive or not technically developed yet to a stage where they can be used ion farms under field conditions.

Concrete is a ubiquitous flooring material in most intensive dairy industries and so we cannot assess the impact of concrete without turning to countries where it is not used. Gitau et al. (1996) studied cattle in Kenya; none were kept on concrete and no sole ulcers or white line disease was reported. This may be of huge importance to our understanding of the etiology of these lesions. The data from New Zealand is similar and horn lesions have increased since concrete standing has been used on farms (Chesterton, 2004). A sudden change from one floor type to another has been reported to affect lameness. Cattle moving from resilient floors, e.g. straw bedded, to hard floors, e.g. concrete, have more lameness (Hultgren and Bergsten, 2001) and lesions (Webster, 2002). This is hypothesized to occur because of the following chain of cause and effects. If animals are moved to a hard floor the claw is exposed to higher pressure, in particular high circumscribed/local load (van der Tol et al., 2004). This pressure stimulates horn production, more horn is produced and the claw gets bigger. Because of the initial asymmetry of the two metatarsal bones (Nacambo et al., 2002) the outer claw on the hind limb is more loaded which causes more stimulation of horn production. As a consequence the claw gets bigger, carries more load and more horn is produced. Thus for cows on hard floor a vicious circle of pressure and horn production is activated. This can only be interrupted by regular professional functional claw trimming. A sudden change onto an abrasive floor may wear out the sole horn before the rate of horn growth has increased. This may explain the thin soles often reported in early lactation cows.

As well as floor material the quality of the floor surface whilst standing or walking also affects cow comfort. Poor quality includes surfaces that are too smooth and lead to slipping, too abrasive leading to wear of hoof horn, too uneven leading to tripping and presence of loose stones that may penetrate the sole, particularly the white line. The quality of concrete in the feeding area, on tracks in the housed environment and tracks to and from pasture have been identified as an associated risk for lameness (Chesterton, 2004), particularly white line disease. Good management of the above will lead to optimal lying times of 14-16 h a day and reduce physical damage to soft and hard tissues of the claw.

As keeping the cows on hard floorings such as concrete can be the cause of a high lameness or claw lesion prevalence (Vokey et al., 2001), an increasing number of farmers install rubber floorings on the walkways. The influence of these soft floorings on animal welfare and claw health has been the issue of numerous investigations. Compared to concrete, cows showed improved gait cycles and both longer step lengths and walking distances (Rushen and Passilé, 2006; Flower et al., 2007; Telezhenko et al., 2017). Furthermore, less slipping and more comfort as well as estrous behavior was observed when cows were kept on rubber flooring (Benz, 2002; Bendel, 2005; Platz et al., 2008). While some authors stated a better claw health on rubber floorings (Benz, 2002; Jungbluth et al., 2003; Eicher et al., 2013), other studies found no improvement (Vokey et al., 2001; Samel, 2005; Boyle et al., 2007) and some even determined an increase of sole ulcers on rubber flooring (Kremer et al., 2007; Fjeldaas et al., 2011).

For a better understanding of the influence of different flooring types on the development of claw lesions, pressure measurement can be applied and has already been used in previous studies (Telezhenko et al., 2008; Bergsten et al., 2015). As the authors used static pressure plates, no direct impact of different flooring characteristics on the sole of the claws was captured (Franck et al., 2006). Therefore, the use of thin pressure-sensitive sensor foils is favorable to analyze the direct interaction between flooring and claw, but they have solely been applied to cattle claws in ex vivo studies so far (Franck et al., 2006; Oehme et al., 2018).

Mechanical risk factors originate from the claw floor interaction, with the quality and resilience of the claw tissues on one side and the properties of the flooring system on the other side being the key factors. Biomechanical risk factors also originate from the shape and geometry of the claw capsule and are therefore directly linked to claw trimming.

The lack of scientific evidence for the world wide used Dutch method of claw trimming, which was developed over 30 years ago, and its variations and modifications is remarkable. Very little peer-reviewed evidence has been published in this area (Archer et al., 2015; Bell, 2015). With our present understanding of the paramount role of biomechanics in the pathogenesis of non-infectious claw lesions we urgently need state of the art biomechanical research looking into the effects trimming has on the interior structures of the foot. We need to generate scientific evidence for optimal trimming preventing mechanical claw lesions from developing. We also need to evaluate flooring and housing systems for their capability to provide the conditions for a biomechanical optimal claw floor interaction preventing claw lesions most effectively.

We have increasing evidence from biomechanical and kinematic studies in vivo and ex vivo that biomechanical forces are a predominant a risk factor for the development of non-infectious of claw lesions (Carvalho et al., 2005; Meyer et al. 2007; Schmid et al. 2008, Van der Tol et al. 2002, 2003; Zeiner et al. 2007). The main factors influencing biomechanics of the bovine foot are: locomotion / standing time, behaviour, flooring, claw trimming, claw conformation, tissue properties – genetics determining claw tissue resilience and functional capacity.

We have established and know for sure that preventive measures must be geared to reducing the mechanical stress level for the sensitive claw tissues. Soft elastic flooring more and more turns out to be a measure of eminent importance. Routine claw trimming is essential and helps to balance the load born by the claw, distributed the load evenly, unload anatomical sensitive regions and avoid local pressure peaks. Cow comfort must be interpreted as part of the interaction between the foot of a dairy cow and its internal and external challenges.

Important areas and topics for future biomechanical research can be identified based on the evidence we have for the role of biomechanics in claw lesion pathogenesis. These foci include: analysis of physiological motion patterns of the bovine distal extremity, studies on the influence of floor conditions and of claw trimming using kinetical analysis, studies on claw horn deformation (Ouweltjes et al., 2016) employing finite element (Hinterhofer et al., 2009) and kinetical analysis and finally further research on the relative motion of the distal phalanx in relation to digital cushion properties and metabolic situation (Newsome et al., 2017). Future work should also employ promising new tools such as biplane high-speed fluoroscopy to gain further insight into the claw floor integration and for evaluation of trimming methods and flooring systems (Weiss et al. 2017, 2019).

References

Alsaaod M, Luternauer M, Hausegger T, Kredel R, Steiner A. 2017. The cow pedogram-analysis of gait cycle variables allows the detection of lameness and foot pathologies. J Dairy Sci. 2017 Feb; 100(2):1417-1426. doi: 10.3168/jds.2016-11678. Epub 2016 Dec 9.

Archer, S. C., R. Newsome, H. Dibble, C. J. Sturrock, M. G. G. Chagunda, C. S. Mason, and J. N. Huxley. 2015. Claw length recommendations for dairy cow foot trimming. Vet. Rec. https://doi.org/10.1136/vr.103197.

Barker ZE, Amory JR, Wright JL, Blowey RW, Green LE. 2007. Management factors associated with impaired locomotion in dairy cows in England and Wales. J Dairy Sci. 2007 Jul; 90(7):3270-7.

Barker, Z. E., K. A. Leach, H. R. Whay, N. J. Bell, and D. C. Main. 2010. Assessment of lameness prevalence and associated risk factors in dairy herds in England and Wales. J. Dairy Sci. 93(3):932–941. https://doi.org/10.3168/jds.2009-2309.

De Belie N, Rombaut E. 2003. Characterisation of claw–floor contact pressures for standing cattle and the dependency on concrete roughness. Biosyst Eng. 2003; 85(3):339–46.

Bell, N. 2015. Evidence-based calw trimmingfpr dairy cattle. Vet Rec 221; 220-221.

Bendel, J. 2005. Auswirkungen von elastischen Bodenbelägen auf das Verhalten von Milchrindern im Laufstall. Dissertation med. vet, München.

Benz, B. 2002. Elastische Beläge für Betonspaltenböden in Liegeboxenlaufställen. Dissertation, Hohenheim.

Bergsten C. 2003. Causes, risk factors, and prevention of laminitis and related claw lesions. Acta Vet Scand Suppl. 2003; 98:157-66.

Bergsten, C., E. Telezhenko, and M. Ventorp. 2015. Influence of Soft or Hard Floors before and after First Calving on Dairy Heifer Locomotion, Claw and Leg Health. Animals (Basel) 5(3):662–686. https://doi.org/10.3390/ani5030378.

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. https://doi.org/10.3168/jds.2008-1827.

Bicalho, R. C., L. D. Warnick, and C. L. Guard. 2008. Strategies to Analyze Milk Losses Caused by Diseases with Potential Incidence Throughout the Lactation: A Lameness Example. J. Dairy Sci. 91(7):2653–2661. https://doi.org/10.3168/jds.2007-0744.

Blackie N, Bleach EC, Amory JR, Scaife JR. 2013. Associations between locomotion score and kinematic measures in dairy cows with varying hoof lesion types. J Dairy Sci. 2013 Jun; 96(6):3564-72. doi: 10.3168/jds.2012-5597. Epub 2013 Mar 30.

Boyle, L. A., J. F. Mee, and P. J. Kiernan. 2007. The effect of rubber versus concrete passageways in cubicle housing on claw health and reproduction of pluriparous dairy cows. Appl. Anim. Behav. Sci. 106:1–12. https://doi.org/10.1016/j.applanim.2006.07.011.

Carvalho, V. 2004. Effects of trimming on dairy-cow hoof-pressure distributions and weight-bearing dynamics during stance phase. Dissertation, Gainesville.

Carvalho, V., Bucklin, R., Shearer, J., Shearer, L., 2005. Effects of trimming on dairy cattle hoof weight bearing and pressure distributions during the stance phase. Transactions of the ASAE 48, 1653– 1659.

Cha, E., J. A. Hertl, D. Bar, and Y. T. Gröhn. 2010. The cost of different types of lameness in dairy cows calculated by dynamic programming. Prev. Vet. Med. 97(1):1–8. https://doi.org/10.1016/j.prevetmed.2010.07.011.

Chapinal N, de Passilé AM, Rushen J. 2009. Weight distribution and gait in dairy cattle are affected by milking and late pregnancy. J Dairy Sci. 2009; 92(2):581–8.

Chesterton RN. 2004. Linking farm physical conditions, herd management and cow behavior to the distribution of foot lesions causing lameness in pasture-fed dairy cattle in New Zealand. Proceedings of the 13th International Symposium and 5th Conference on Lameness in Ruminants, 2004, 200-202.

Cook NB, Bennett TB, Nordlund KV. 2004. Effect of free stall surface on daily activity patterns in dairy cows with relevance to lameness prevalence. J Dairy Sci. 2004 Sep; 87(9):2912-22

Cook NB, Nordlund KV. 2009. The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. Vet J. 2009 Mar; 179(3):360-9. Epub 2007 Nov 5.

Dunthorn J, Dyer RM, Neerchal NK, McHenry JS, Rajkondawar PG, Steingraber G, Tasch U. 2015. Predictive models of lameness in dairy cows achieve high sensitivity and specificity with force measurements in three dimensions. J Dairy Res. 2015 Nov; 8 2(4):391-9. doi: 10.1017/S002202991500028X. Epub 2015 Aug 17.

Eicher, S. D., D. C. Lay, J. D. Arthington, and M. M. Schutz. 2013. Effects of rubber flooring during the first 2 lactations on production, locomotion, hoof health, immune functions, and stress. J. Dairy Sci. 96(6):3639–3651. https://doi.org/10.3168/jds.2012-6049.

Fessl L. 1974. Activity of joints in cattle during walking. A contribution to movement analysis in cattle. Dtsch Tierarztl Wochenschr. 1974 Mar 15; 81(6):129-32.

Fjeldaas, T., A. M. Sogstad, and O. Osterås. 2011. Locomotion and claw disorders in Norwegian dairy cows housed in freestalls with slatted concrete, solid concrete, or solid rubber flooring in the alleys. J. Dairy Sci. 94(3):1243–1255. https://doi.org/10.3168/jds.2010-3173.

Flower, F. C., A. M. de Passilé, D. M. Weary, D. J. Sanderson, and J. Rushen. 2007. Softer, Higher-Friction Flooring Improves Gait of Cows With and Without Sole Ulcers. J. Dairy Sci. 90(3):1235–1242. https://doi.org/10.3168/jds.S0022-0302 (07)71612-0.

Franck, A., G. Cocquyt, P. Simoens, and N. De Belie. 2006. Biomechanical Properties of Bovine Claw Horn. Biosyst Eng 93(4):459–467. https://doi.org/10.1016/j.biosystemseng.2006.01.007.

Gitau T, McDermott JJ, Mbiuki SM.1996. Prevalence, incidence and risk factors for lameness in dairy cattle in small-scale farms in Kikuyu Division, Kenya. Prev. Vet. Med., 1996, 28:01-115.

Ghotoorlar SM, Ghamsari SM, Nowrouzian I, Ghotoorlar SM, Ghidary SS. 2012. Lameness scoring system for dairy cows using force plates and artificial intelligence. Vet Rec. 2012 Feb 4; 170(5):126. doi: 10.1136/vr.100429. Epub 2011 Dec 2

Heringstad B, Egger-Danner C, Charfeddine N, Pryce JE, Stock KF, Kofler J, Sogstad AM, Holzhauer M, Fiedler A, Müller K, Nielsen P, Thomas G, Gengler N, de Jong G, Ødegård C, Malchiodi F, Miglior F, Alsaaod M, Cole JB. 2018. Invited review: Genetics and claw health: Opportunities to enhance claw health by genetic selection. J Dairy Sci. 2018 Jun; 101(6):4801-4821. doi: 10.3168/jds.2017-13531. Epub 2018 Mar 7.

Herlin, A.H., Drevemo, S., 1997. Investigating locomotion of dairy cows by use of high speed cinematography. Equine Veterinary Journal Supplement, 106–109.

Hilger, J., and U. Passarge. 2018. Jahresbericht 2017. Sächsischer Landeskontrollverband e.V., Niederwiesa.

Hinterhofer C, Ferguson JC, Apprich V, Haider H, Stanek C. 2006. Slatted floors and solid floors: stress and strain on the bovine hoof capsule analyzed in finite element analysis. J Dairy Sci. 2006 Jan; 89(1):155-62.

Hinterhofer C, Haider H, Apprich V, Ferguson JC, Collins SN, Stanek C. 2009. Development of a twenty-one-component finite element distal hind limb model: stress and strain in bovine digit structures as a result of loading on different floorings. J Dairy Sci. 2009 Mar; 92(3):972-9. doi: 10.3168/jds.2008-1605.

Holah DE et al. 2002. The histology and histopathology of the support structures in the laminated region of the bovine hoof in maiden heifers and around the time of first calving. In: III International Conference on Bovine Lameness. Parma, Italy 2002, pp 109-111.

Hultgren J, Bergsten C. 2001. Effects of a rubber-slatted flooring system on cleanliness and foot health in tied dairy cows. Prev Vet Med. 2001 Nov 2; 52(1):75-89.

Huth C, Russke A, Alsleben B, Hamann H, Distl O. 2005. Body and claw measurements as well as pressure distribution under the claws in heifers of different cattle breeds. Berl Munch Tierarztl Wochenschr. 2005 Mar-Apr; 118(3-4):150-9.

Jungbluth, T., B. Benz, and H. Wandel. 2003. Soft walking areas in loose housing systems for dairy cows. p. 171–177. In American Society of Agricultural and Biological Engineers (ed.). Fifth International Dairy Housing Proceedings of the 29-31 January 2003 Conference, Fort Worth, Texas, USA, Fort Worth, Texas, USA.

Knott, L., J. F. Tarlton, H. Craft, and A. J. F. Webster. 2007. Effects of housing, parturition and diet change on the biochemistry and biomechanics of the support structures of the hoof of dairy heifers. Vet. J. 174(2):277–287. https://doi.org/10.1016/j.tvjl.2006.09.007.

Kremer, P. V., S. Nueske, A. M. Scholz, and M. Foerster. 2007. Comparison of Claw Health and Milk Yield in Dairy Cows on Elastic or Concrete Flooring. J. Dairy Sci. 90(10):4603–4611. https://doi.org/10.3168/jds.2006-549.

Kujala M, Pastell M, Soveri T. 2008. Use of force sensors to detect and analyze lameness in dairy cows. Vet Rec. 2008 Mar 22; 162(12):365-8.

Liang, D., L. M. Arnold, C. J. Stowe, R. J. Harmon, and J. M. Bewley. 2017. Estimating US dairy clinical disease costs with a stochastic simulation model. J. Dairy Sci. 100(2):1472–1486. https://doi.org/10.3168/jds.2016-11565.

Lischer ChJ, Ossent P, Räber M, Geyer H. 2002. The suspensory structures and supporting tissues of the bovine third phalanx of cows and their relevance to the development of typical sole ulcers (Rusterholz ulcers). Vet Rec, 2002, 151:694-698.

Maierl, J., R. Bohmisch et al. 2002. A method of biomechanical testing the suspensory apparatus of the third phalanx in cattle: a technical note. Anat Histol Embryol. 31(6):321-325.

Mangweth G, Schramel JP, Peham C, Gasser C, Tichy A, Altenhofer C, Weber A, Kofler J. 2012. [Lameness detection in cows by accelerometric measurement of motion at walk. Berl Munch Tierarztl Wochenschr. 2012 Sep-Oct; 125(9-10):386-96.

Meyer, S. W. 2006. Hochfrequenzkinematographische Untersuchungen des Fussungsvorganges von Rindern auf dem Laufband. Dissertation med. vet, Zürich.

Meyer, S., Weishaupt, M., Nuss, K., 2007. Gait patterns of heifers before and after claw trimming: A high-speed cinematographic study on a treadmill. Journal of Dairy Science 90, 670–676.

Mülling, C., and C. J. Lischer. 2002. New aspects on etiology and pathogenesis of laminitis in cattle. p. 236–247. In M. Kaske, H. Scholz, and M. Höltershinken (eds.). Proceedings of the XXII World Buiatrics Congress, Hannover, 18.-23.08.2002, Hannover.

Mülling, Ch.KW, Frohberg-Wang D et al. 2004. Matrix overloaded – Structural alterations of claw connective tissue and their functional implications. Proceedings of the 13th International Symposium on Lameness in Ruminants, Maribor/Slovenia, 2004, 79-82.

Nacambo S, Häsig M et al. 2004. Difference in length of the metacarpal and metatarsal condyles in claves and the correlation to claw size. Proceedings of the 13th International Symposium on Lameness in Ruminants, Maribor/Slovenia, 2004, 104-106.

Newsome, R., M. J. Green, N. J. Bell, M. G. G. Chagunda, C. S.Mason, C. J. Sturrock, H. R. Whay, and J. N. Huxley. 2016. Linking bone development on the caudal aspect of the distal phalanx with lameness during life. J. Dairy Sci. 99:4512–4525. https://doi. org/10.3168/jds.2015-10202.

Newsome, R. F., M. J. Green, N. J. Bell, C. S. Mason, H. R. Whay, and J. N. Huxley. 2017. A prospective cohort study of the digital cushion and corium. Part 1: Associations with body condition, lesion incidence and proximity to calving. J. Dairy Sci. 100:4745–4758.

Newsome, R. F., M. J. Green, N. J. Bell, C. S. Mason, H. R. Whay, and J. N. Huxley. 2017. A prospective cohort study of the digital cushion and corium. Part 2: Does thinning of the digital cushion and corium lead to lameness and claw horn disruption lesions? J.Dairy Sci. 100:4759–4771. https://doi.org/10.3168/jds.2016-12013.

Nilson, S. 1963. Clinical, morphological and experimental studies of laminitis in cattle, Acta Veetrianria Scandinavica 4(1), 1963.

Nuss, K., N. M. Waldern, M. A. Weishaupt, and T. Wiestner. 2015. Kinetische Auswertung des Schrittes von Jungrindern und Kühen auf einem instrumentierten Laufband. Tierarztl Prax Ausg G Grosstiere Nutztiere 43(2):73–80. https://doi.org/10.15653/TPG-140517.

Oehme, B., S. M. Geiger, S. Grund, K. Hainke, J. Munzel, and C. K. W. Mülling. 2018. Effect of different flooring types on pressure distribution under the bovine claw - an ex vivo study. BMC Vet Res 14(1):259. https://doi.org/10.1186/s12917-018-1579-9.

Ouweltjes W, Gussekloo SW, Spoor CW, van Leeuwen JL. 2016. A new technique using roentgen stereophotogrammetry to measure changes in the spatial conformation of bovine hind claws in response to external loads. Vet J. 2016 Feb; 208:81-6. doi: 10.1016/j.tvjl.2015.07.010. Epub 2015 Jul 14.

Pastell ME1, Kujala M. 2007. A probabilistic neural network model for lameness detection. J Dairy Sci. 2007 May; 90(5):2283-92.

Platz, S., F. Ahrens, J. Bendel, H. H. D. Meyer, and M. H. Erhard. 2008. What Happens with Cow Behavior When Replacing Concrete Slatted Floor by Rubber Coating: A Case Study. J. Dairy Sci. 91(3):999–1004. https://doi.org/10.3168/jds.2007-0584.

Pluk A, Bahr C, Poursaberi A, Maertens W, van Nuffel A, Berckmans D. 2012. Automatic measurement of touch and release angles of the fetlock joint for lameness detection in dairy cattle using vision techniques. J Dairy Sci. 2012 Apr; 95(4):1738-48. doi: 10.3168/jds.2011-4547.

Rajkondawar PG, Liu M, Dyer RM, Neerchal NK, Tasch U, Lefcourt AM, Erez B, Varner MA. 2012. Comparison of models to identify lame cows based on gait and lesion scores, and limb movement variables. J Dairy Sci. 2006 Nov; 89(11):4267-75.

Razak AH, Zayegh A, Begg RK, Wahab Y. 2012. Foot plantar pressure measurement system: a review. Sensors (Basel). 2012; 12(7):9884-912. Epub 2012 Jul 23.

Räber M, Geyer H et al. 2004. The bovine digital cushion – a descriptive anatomical study. The Veterinary Journal, 2004, 167:258-264.

Räber M, Scheeder MR, Ossent P, Lischer ChJ, Geyer H. 2006. The content and composition of lipids in the digital cushion of the bovine claw with respect to age and location--a preliminary report. Vet J. 2006 Jul; 172(1):173-7.

Rushen, J., and A. M. de Passilé. 2006. Effects of Roughness and Compressibility of Flooring on Cow Locomotion. J. Dairy Sci. 89(8):2965–2972. https://doi.org/10.3168/jds.S0022-0302(06)72568-1.

Rusterholz, A. 1920. Das spezifisch-traumatische Klauensohlengeschwür des Rindes-Teil 1. SAT 62 (10). 421-446. http://dx.doi.org/10.5169/seals-591227.

Rusterholz, A. 1920. Das spezifisch-traumatische Klauensohlengeschwür des Rindes-Teil 2. SAT 62 (11). 505-525. http://dx.doi.org/10.5169/seals-591230.

Samel, M. 2005. Gummibeschichtete Laufflächen für Milchkühe und deren Einfluss auf Klauenwachstumsparameter und Klauengesundheit im Vergleich zu betonierten Laufflächen. Dissertation med. vet, Hannover.

Schmid J, Magnenat-Thalmann N. 2008. MRI bone segmentation using deformable models and shape priors. Med Image Comput Comput Assist Interv. 2008;11(Pt 1):119-26.

Spielmann, C. 1984. Konstruktion und Bau einer Messanlage zur Kraft- und Druckverteilung unter Rinderklauen, Diss. med. vet., München.

Tarlton JF et al. 2000. Biomechanical and histopathological changes in the support structures of the bovine hooves around the time of first calving. Vet J, 2000, 163(2):196-204.

Tarlton JF, Holah DE, Evans KM, Jones S, Pearson GR, Webster AJ. 2002. Biomechanical and histopathological changes in the support structures of bovine hooves around the time of first calving. Vet J. 163(2):196-204

Telezhenko, E., C. Bergsten, M. Magnusson, M. Ventorp, and C. Nilsson. 2008. Effect of Different Flooring Systems on Weight and Pressure Distribution on Claws of Dairy Cows. J. Dairy Sci. 91(5):1874–1884. https://doi.org/10.3168/jds.2007-0742.

Telezhenko, E., M. Magnusson, and C. Bergsten. 2017. Gait of dairy cows on floors with different slipperiness. J. Dairy Sci. 100:1–10. https://doi.org/10.3168/jds.2016-12208.

Thorup VM, do Nascimento OF, Skjøth F, Voigt M, Rasmussen MD, Bennedsgaard TW, Ingvartsen KL. 2014. Short communication: Changes in gait symmetry in healthy and lame dairy cows based on 3-dimensional ground reaction force curves following claw trimming. J Dairy Sci. 2014 Dec; 97(12):7679-84. doi: 10.3168/jds.2014-8410. Epub 2014 Oct 11.

van der Tol PP, Metz JH, Noordhuizen-Stassen EN, Back W, Braam CR, Weijs WA. 2002. The pressure distribution under the bovine claw during square standing on a flat substrate. J Dairy Sci. 2002 Jun;85(6):1476-81 van der Tol, P. P. J., J. H. M. Metz, E. N. Noordhuizen-Stassen, W. Back, C. R. Braam, and W. A. Weijs. 2003. The Vertical Ground Reaction Force and the Pressure Distribution on the Claws of Dairy Cows While Walking on a Flat Substrate. J. Dairy Sci. 86(9):2875–2883. https://doi.org/10.3168/jds.S0022-0302(03)73884-3.

van der Tol, P. P. J., S. S. van der Beek, J. Metz, E. N. Noordhuizen-Stassen, W. Back, C. R. Braam, and W. A. Weijs. 2004. The Effect of Preventive Trimming on Weight Bearing and Force Balance on the Claws of Dairy Cattle. J. Dairy Sci. 87(6):1732–1738. https://doi.org/10.3168/jds.S0022-0302(04)73327-5.

Viazzi S, Bahr C, Schlageter-Tello A, Van Hertem T, Romanini CE, Pluk A, Halachmi I, Lokhorst C, Berckmans D. 2013. Analysis of individual classification of lameness using automatic measurement of back posture in dairy cattle. J Dairy Sci. 2013 Jan; 96(1):257-66. doi: 10.3168/jds.2012-5806. Epub 2012 Nov 17.

Vokey, F. J., C. L. Guard, H. N. Erb, and D. M. Galton. 2001. Effects of Alley and Stall Surfaces on Indices of Claw and Leg Health in Dairy Cattle Housed in a Free-Stall Barn. J. Dairy Sci. 84(12):2686–2699. https://doi.org/10.3168/jds.S0022-0302(01)74723-6.

Walker, A. M., T. Pfau, A. Channon, and A. Wilson. 2010. Assessment of dairy cow locomotion in a commercial farm setting: The effects of walking speed on ground reaction forces and temporal and linear stride characteristics. Res. Vet. Sci. 88(1):179–187. https://doi.org/10.1016/j.rvsc.2009.05.016.

Webster AJF. 2001. Effects of housing and two forage diets on the development of claw horn lesions in dairy cows at first calving and in first lactation. Veterinary Journal, 2001, 162:56-65.

Webster, AJF. 2003. Assessment of the welfare of dairy cattle using animal based measurements: direct observations and investigation of farm records. Vet Rec, 2003, 153:197-202.

Webster, AJF, Knott L, Tarlton JF. 2005. Understanding laments in the dairy cow. Cattle Practice, 2005, 13(2) 93-98.

Weiss M, Reich E, Grund S, Mülling CKW, Geiger SM. 2017. Validation of 2 noninvasive, markerless reconstruction techniques in biplane high-speed fluoroscopy for 3-dimensional research of bovine distal limb kinematics. J Dairy Sci. 2017 Oct; 100(10):8372-8384. doi: 10.3168/jds.2017-12563. Epub 2017 Aug 2.

Weiss M, Hainke K, Grund S, Gerlach K, Mülling CKW, Geiger SM. 2019. Does the range of motion in the bovine interphalangeal joints change with flooring condition? A pilot study using biplane high-speed fluoroscopic kinematography. J Dairy Sci. 2019 Feb; 102(2):1443-1456. doi: 10.3168/jds.2018-14844. Epub 2018 Dec 24.

Westerfeld, I., Ch. K. W. Mülling and K.-D. Budras. 2000. Suspensory apparatus of the distal phalanx (Ph III) in the bovine hoof. XI International symposium on disorders of the ruminant digit and III International conference on bovine lameness, Parma, Italy, 2000. 103-105.

Westerfeld, I., R. M. Hirschberg and K.-D. Budras. 2004. The weight bearing apparatus of the bovine claw. Proceedings of the 13. International Symposium on Lameness in Ruminants Maribor/Slovenia, 11. - 14- 2. 2004. 66-67.

Winckler, C., and G. Brill. 2004. Lameness prevalence and behavioual traits in cubicle housed dairy herds – a field study. p. 160–161. In B. Zemljic (ed.). Proceedings of the 13th International Symposium and 5th Conference on Lameness in Ruminants, Maribor, Slovenija, 11.02.-15.02. 2004, Maribor, Slovenija.

Zeiner, H., H. Schobesberger, M. Skalicky, and C. Stanek. 2007. Effect of different claw trimming methods on the pressure distribution under the bovine claw - an in vitro study. Berl. Munch. Tierarztl. Wochenschr. 120(3/4):165–172.

What should Artificial Intelligence and Computer Vision tools Do for You in the Near Future?

Dorte Dopfer
School of Veterinary Medicine, UW-Madison, Wisconsin, USA

Concepts and Background

Applications of Artificial Intelligence (AI) and Computer Vision tools are becoming more popular in agricultural settings and expectations are that such tools will be routinely applied to cattle husbandry in the near future. Corporate projects to identify and monitor cows (Taylor 2018; Irish Journal, 2018) and research to automatically detect lameness and to estimate bodyweight have been reported recently (Song et al., 2008; Van Hertem et al., 2013; Fernandes et al., 2018). In addition, the field of precision dairy farming will explore many applications of Artificial Intelligence models in the near future. The field and methods for Computer Vision models are developing so rapidly that today's abstract will likely be outdated by the time of the presentation. Large volumes of food animal production and health data collected over prolonged periods of time continue to become available while storage and processing capacities are moving into the 'Cloud' making Computer Vision models, Deep Learning about 'Big Data' and their applications increasingly affordable and accessible.

This talk wants to describe the need for lameness detection and detection of claw lesions such as Digital dermatitis (DD, syn. Hairy Heel Warts) in real time. There are many opportunities for the installation of cameras for image generation, but the limitations of the current Computer Vision algorithms have to be overcome to make these tools applicable in real time more widely. The presentation will summarize the current developments and demonstrate applications of such models. Workshops to teach Artificial Intelligence tools to producers, hoof trimmers, veterinarians and students of agriculture and dairy sciences will emerge in the near future transforming the audiences and professions in agriculture, the long-term monitoring of food animals including our concepts and definitions for health and disease. The practice in the medical and agricultural professions will change as a consequence. If a disconnection between the generations of AI users, programmers and corporate professionals is to be prevented, getting involved in the application of AI tools and communication about the needs for such tools in agriculture is an immediate priority.

Acknowledgements

Special thanks go to Jamie Sullivan (Rippleview Hoofcare, Manitoba, Canada) and Christopher Bauer, (Hoof trimmer at Monrovi, Wisconsin, USA) for their support of the image collection.

Charlie Harding (xxxxxxxx, UK) is thanked very much for the use of his cow lameness video footage.

References

Apr 13, T.A.P. · P., 2018 3:31 PM ET | Last Updated: April 13, and 2018. 2018. Farmers Are Using AI to Help Monitor Cows | CBC News. Accessed January 16, 2019. https://www.cbc.ca/news/technology/cows-artificial-intelligence-1.4618981.

Fernandes, A., J. Dorea, R. Fitzgerald, W. Herring, and G.J.M. Rosa. 2018. A novel automated system to acquire biometric and morphological measurements, and predict body weight of pigs via 3D computer vision.. J Animal Sci.

Song, X., T. Leroy, E. Vranken, W. Maertens, B. Sonck, and D. Berckmans. 2008. Automatic detection of lameness in dairy cattle—Vision-based trackway analysis in cow's locomotion. Computers and Electronics in Agriculture 64:39–44. doi:10.1016/j.compag.2008.05.016.

Taylor, C. Facial Recognition for Cows in Focus as Irish Start-up Cainthus Gets Backing. Accessed January 16, 2019. https://www.irishtimes.com/business/technology/facial-recognition-for-cows-in-focus-as-irish-start-up-cainthus-gets-backing-1.3376545.

Van Hertem, T., S. Viazzi, C. Eduardo Bites Romanini, C. Bahr, D. Berckmans, A. Schlageter Tello, K. Lokhorst, D. Rozen, E. Maltz, and I. Halachmi. 2013. Automatic lameness detection by computer vision and behavior and performance sensing. Page.

Microbiology of causative bacteria of Bovine Digital Dermatitis

Prof. Naoaki Misawa (DVM, PhD)
Center for Animal Disease Control, University of Miyazaki, Japan
1-1 Gakuenkibanadai-nishi, Miyazaki 889-2192, Japan
Email: a0d901u@cc.miyazaki-u.ac.jp

Bovine digital dermatitis (BDD) is an infectious foot disease in cattle which was first reported in Italy in 1974 and is now recognized throughout the world. In Japan, BDD in dairy cattle is now found in most regions since the first case was reported in 1992. BDD begins as a superficial dermatitis with an erosive lesion and later forms a hyperkeratotic papillomatous lesion with long hair-like projections. These lesions are usually located on the rear of the foot between the bulbs of the heel. BDD often leads to lameness and decreases in body weight and milk production, causing economic loss and animal welfare problems.

It is suspected that BDD is caused by bacteria, since treatment with antibiotics such as oxytetracycline and penicillin G results in rapid resolution of the lesions. Microscopic examinations of biopsies or direct stamp preparations of the lesions show various bacterial morphotypes, including long filaments, rods, coccoids, and helices. Although several culturable bacteria have been isolated from BDD lesions, it remains unclear whether all are involved in the etiology.

Among the bacteria detected in BDD lesions, a large number of spirochetes are observed. Choi *et al*. detected five spirochetal phylotypes using 16S rRNA gene sequence analysis. Similarly, Moter *et al*. detected four spirochetal phylotypes by using *in situ* hybridization with oligonucleotide probes of the 16S rRNA gene from treponemes. Indeed, several *Treponema* species have been isolated from dairy cattle with BDD, and are closely related to oral *Treponema* species in humans, including *T. phagedenis*, *T. denticola*, *T. vincentii*, and *T. medium*. Furthermore, Schrank *et al*. isolated and characterized the newly proposed species *Treponema brennaborense*. These reports suggest that multiple *Treponema* species are present in BDD lesions. Their presence in both superficial lesions and deeper layers of the dermis suggests that they play an important role in the infection. However, it has not been proved that these organisms satisfy Koch's postulates.

One possible reason why the etiology of BDD is not yet fully understood is the difficulty of isolating and culturing *Treponema* species present in BDD lesions. Several research groups have isolated *Treponema* species by the use of methods for the isolation of oral treponemes in humans. An immuno-magnetic bead method using polyclonal antibodies against *T. denticola* and *T. vincentii* was used to separate *Treponema* from other bacteria. The growth rate of many *Treponema* species is poor, and the presence of other fast-growing bacteria in BDD lesions often prevents their isolation. No selective media supplemented with suitable antimicrobial agents for the primary isolation of treponemes from BDD lesions have been developed. Here, we sought to isolate treponemes from cattle with BDD lesions for the first time in Japan. We developed a simple two-step culture method which improved the rate of isolation of spirochetes, and examined the biochemical characteristics and 16S rRNA gene sequences for phylogenic analysis. Finally, we examined the genotypic heterogeneity among the strains by molecular typing methods.

All spirochetes isolated were catalase-positive and oxidase-negative and showed weak β-hemolytic activity. Enzyme activities were identical to those of *T. phagedenis* ATCC27087. Sequencing of the 16S rRNA gene showed that all strains isolated had >99% identity to those of the *T. phagedenis* type strain and of *T. phagedenis*-like strains isolated predominantly from BDD lesions in the USA and Europe. Pulsed-field gel electrophoresis and PCR-based random amplified polymorphism DNA methods revealed considerable diversity among strains isolated not only from different cattle but also from the same individuals. These findings may provide further evidence for the role of these treponemes in the pathogenesis of persistent BDD.

To study the bacterial community, we used 16S rRNA gene sequencing of randomly selected clones based on PCR with minimum amplification cycles to search for organisms present in BDD lesions but not in healthy foot skin. The nucleotide sequences of 1525 clones from 5 BDD lesions (836 clones) and 4 samples of healthy foot skin (689 clones) were determined and grouped into 316 operational taxonomic units (OTUs) with a cut-off value of >99% sequence identity. Two OTUs, P-01 (143 clones; 100% nucleotide sequence identity with *Treponema phagedenis*) and P-02 (112 clones; 86% identity with *Bacteroidetes*), were detected most frequently in all BDD samples examined. In contrast, OTU N-01 (87 clones), showing 99% nucleotide sequence identity with *Moraxella phenylpyruvica*, was the most prevalent in the normal samples examined. Spirochaetes were detected in only 1 sample. Phylogenetic analysis showed that *T. denticola*-like and *T. phagedenis*-like spirochetes were the predominant groups in the BDD lesions. Detection of multiple treponemes and an unknown bacterium close to *Bacteroides* sp. at high rates by a culture-independent approach could be evidence of the association of these organisms with BDD.

Lesions of BDD are treated with antibiotics, usually lincomycin or oxytetracycline after physically removing the lesion. Although such a conventional treatment is effective, milk cannot be brought to market during the treatment due to the possible residue of antibiotics in milk. Allyl isothiocyanate (AITC), an extract of *Wasabia japonica* (a plant of family *Brassicaceae*; known as wasabi or Japanese horseradish), may be used as an alternative antimicrobial agent that overcome this issue. We evaluated the effectiveness of AITC in BDD treatment and compare it with that of lincomycin. We evaluated the effectiveness by inspecting the change in the clinical severity of the lesions, according to the disease classes (scoring of lesions consisted of six stages) described by Döpfer and by determining the change of bacterial population in BDD lesions by means of 16S-based metagenomic analysis using a next generation sequencer. We further analyzed the population of selected BDD lesions at species level by analyzing random clone libraries of full-length 16S rRNA gene. The results revealed that AITC is clinically as effectively as lincomycin and also in terms of eradiation of *Treponema* spp., which are the suspected major causative agents of BDD, but more divergent microbes were detected after AITC treatment than after lincomycin treatment. The present data indicate the potential usability of AITC for the treatment of BDD.

Prevention of Lameness from a Nutritional Point of View

A. Gomez*, A. Geiger, G. Xu, R. Chan, J. Weyers, H. McConochie and M. Socha.

Zinpro Corporation, Eden Prairie, MN

Lameness is one of the four key reasons why cattle are often removed from dairy herds (lameness, mastitis, reproduction, and milk production) and is a worldwide issue that can be found in all types of production systems. Considering that the cost of lameness has been estimated to often exceed $300 USD per case, it significantly affects the profitability of farms worldwide. The cause of lameness is multi-factorial in that one factor rarely causes an outbreak within a farm. Such factors include, but are not limited to, time budget management, freestall design and comfort, walking surfaces, hygiene, and footbath protocols and inflammatory challenges. One factor that often receives attention first is nutrition

. Even though disagreements are common on nutritional causation of lameness, a more agreeable statement may be to say that nutrition can be a key predisposing factor in certain situations since nutritional deficiencies or inadequacies in addition to stress may create a perfect storm when environmental challenges are present.

Nutritionally, acidosis is often attributed to being the primary cause of lameness on many farms, particularly subacute ruminal acidosis (SARA). The proposed mechanism involves a cascade of events which begins with a feeding regimen that results in ruminal production of volatile fatty acids and/or lactic acid that exceeds the buffering capacity and removal rate of these acids, thus lowering the rumen pH below 5.5 for an extended period of time (Nocek, 1997). Such scenarios include, but are not limited to, excessive fermentable carbohydrates, finely chopped forage, poor feeding management, and an inverse ratio of concentrate to forage. The lowered rumen pH will increase the release of endotoxins due to the death of gram negative bacteria. Increased ruminal endotoxin concentrations increases the risk of these endotoxins entering the circulatory system of the cow, stimulating pro-inflammatory mediators and vascular changes in the hoof. The disruption in blood flow alters delivery of oxygen and nutrients to the claw, thereby impairing claw horn development and causing a non-infectious inflammation of the corium. Even though ruminal acidosis has been shown to cause systemic inflammation (Xu et al., 2017), nutritional models designed to recreate laminitis have been inconsistent and many of these models have been based on equine models (Garner et al., 1974; Van Eps and Pollitt, 2006), thus making the previously mentioned pathway contentious in some circles.

Development of healthy keratinocytes requires a significant quantity of sulfur-containing amino acids (Tomlinson et al., 2003). Specifically, disulfide bonds between Cys residues play a key role in providing cell wall rigidity and is part of the final stage of keratinization. However, specific amino acid requirements for optimal hoof development have not been established. Excessive soluble protein may be detrimental to hoof horn development. Offer et al. (2003) demonstrated that heifers fed a diet containing a wet, fermented grass silage-based diet vs. an unfermented straw diet from 3 to 30 months of age had greater sole and white line lesions during the rearing period that persisted into the first lactation. Similar findings were observed by Offer et al. (2001).

Very importantly, the effect of glucose availability on keratinocyte growth and survival has been evidenced in several trials (Duarte et al., 2014, Mulling et al. 2016). Keratinocyte survival and growth is affected in a greater extent by the lack of glucose that by oxygen deprivation. Increased (subclinical) inflammation, particularly from digestive upsets, it is likely to alter the formation and rate of horn growth.

Biotin is critically important for improving the keratinization process through its role as a cofactor in several metabolic pathways (Tomlinson et al., 2003). Specifically, biotin is required for the formation of lipids in the intercellular cementing substance. Even though ruminants have the ability to produce biotin in the rumen, Schwab et al. (2006) demonstrated that apparent synthesis of biotin in the rumen does not meet the requirements of a high producing dairy cow. Supplementation with 20 mg of biotin has been commonly recommended on farms to reduce lameness as this has been the effective dose in some studies (Fitzgerald et al., 2000; Pötzsch et al., 2003).

Though required in small quantities, trace minerals play critical roles in maintaining epithelial integrity. Zinc has a critical role in maintaining the health and integrity of skin due to its role in cellular repair and replacement. (Miller et al., 1988). The metabolic actions of zinc include carbohydrate and energy metabolism, protein synthesis, nucleic acid metabolism, epithelial tissue integrity, cell repair and division, and vitamin A transport and utilization (Cousins and King, 2004). Supplementation with zinc methionine reduced incidence of interdigital dermatitis and heel cracks in lactating dairy cattle (Moore et al., 1989).

Copper is active in neutrophil production and affects phagocyte killing ability. Copper is required for antibody development and lymphocyte replication. Copper, in combination with zinc, plays a role in superoxide dismutase activity and the removal of oxygen free radicals. It is therefore a key component in the protective mechanism of cellular membranes against superoxide free radical damage. Copper is also involved in collagen formation as a co-factor in lysyl oxidase and it is essential for disulfide crosslinking of keratin in hoof horn.

Manganese plays an important role in removing superoxide radicals produced by active immune cells. Manganese is a key mitochondrial element as Mn dependent superoxide dismutase protects fragile mitochondrial membranes from attack by free radicals. It has been reported to increase antibody titers and other nonspecific resistance factors in certain animals. Interaction of manganese with neutrophils and macrophages has also been demonstrated. Increasing manganese status has been shown to enhance the killing ability of macrophages via increased enzymatic activity within non-specific immunity. Manganese improves immune function through enhancement of macrophage killing ability.

Cobalt is utilized by rumen bacteria for the synthesis of vitamin B_{12}. Vitamin B_{12} is required as a cofactor for gluconeogenesis. As mentioned previously, glucose is highly required for the development of new keratinocytes. Vitamin B_{12} is also required for methionine synthase in the S-adenosyl methionine cycle and plays an important role as a methyl donor.

Iodine is highly involved in the immune system (Woeber and Ingbar, 1972). It is known for improving immune cell chemotaxis,, phagocytosis and killing ability, through its role in generating cytotoxic reactive species within macrophages (Klebanoff, 1968). Enhancement of the immune system has been the proposed mechanism by which iodine may aid in controlling foot rot in cattle (Maas et al., 1984).

Due to the complimentary roles trace minerals play among each other, there is a benefit of providing a combination of highly available trace mineral sources. Ballentine et al. (2002) fed amino acid complexes of Zn, Mn, and Cu with Co glucoheptonate and found that cows fed these organic trace minerals tended to have less claw disorders at 75 d postpartum (34.1 vs. 23.6%) and numerically less at 250 d postpartum (17.7 vs. 10.0%). There was also a reduction in white line disease at 75 (14.6 vs. 9.5%) and 250 d (8.8 vs. 4.9%) postpartum. Similarly, Siciliano-Jones et al. (2008) decreased incidence of sole ulcers (16.4 vs. 8.5%) 36 wk postpartum when a portion of the inorganic Zn, Mn, Cu and Co were replaced by amino acid complex sources of Zn, Mn and Cu and Co glucoheptonate.

Gomez et al. (2014) evaluated the impact of a heifer mineral supplement containing higher than normal concentrations of zinc, manganese, copper, cobalt, and iodine found in typical heifer mineral mixes. This mineral supplement also contained higher than typical concentrations of metal-amino acid complexes. Holstein steers were experimentally inflicted with DD lesions (Gomez et al., 2012). However feeding steers metal-amino acid complexes tended to reduce incidence of M2 lesions by 45%. Furthermore, in the steers that developed lesions, the size of lesions were reduced by 35%.

In summary, lameness is a very costly disease in the dairy industry worldwide. Though not always the direct cause of lameness, poor nutrition is often a predisposing factor that exasperates the negative impact that poor management and environmental conditions have on foot health. A nutritionally sound ration that provides the optimal supplementation of macro and trace nutrients in addition to proper feeding management are key control points for preventing lameness.

References

Ballantine, H. T., M. T. Socha, D. J. Tomlinson, A. B. Johnson, A. S. Fielding, J. K. Shearer and S. R. Van Amstel. 2002. Effects of feeding complexed zinc, manganese, copper and cobalt to late gestation and lactating dairy cows on claw integrity, reproduction and lactation performance. The Prof. Animal Sci. 18:211-218.

Cousins, R. J. and J. C. King. 2004. Zinc. In Modern Nutrition in Health and Disease. M. E. Shils, A. C. Ross and R. J. Cousins, eds. Philadelphia: Leas and Febiger.

da Silva Duarte I, Gragnani A, Ferreira LM. Dimethyl sulfoxide and oxidative stress on cultures of human keratinocytes. *Can J Plast Surg*. 2004;12(1):13-6

Fitzgerald, T., B. W. Norton, R. Elliott, H. Podlich, and O. L. Svendsen. 2000. The influence of long-term supplementation with biotin on the prevention of lameness in pasture fed dairy cows. J. Dairy Sci. 83:388-344.

Garner, H. E., J. R. Coffman, A. W. Hahn, D. P. Hutcheson, and M. E. Tumbleson. 1975. Equine laminitis of alimentary origin: An experimental model. American Journal of Veterinary Research. 36: 441-444.

Gomez, A., N. Bernardoni, J. Rieman, A. Dusick, R. Hartshorn, D. H. Read, M. T. Socha, N. B. Cook, and D. Döpfer. 2014. A randomized trial to evaluate the effect of a trace mineral premix on the incidence of active digital dermatitis in lesions in cattle. J. Dairy Sci. 97:6211.

Gomez, A., N. B. Cook, N. D. Bernardoni, J. Rieman, A. F. Dusick, R. Hartshorn, M. T. Socha, D. H. Read, and D. Döpfer. 2012. An experimental infection model to induce digital dermatitis infection in cattle. J. Dairy Sci. 95:1821.

Klebanoff, S. J. 1968. Myeloperoxidase-halide-hydrogen peroxide antibacterial system. J. Bacteriol. 25:2131.

Lean, I. J., C. T. Westwood, H. M. Golder, J. J. Vermunt. 2013. Impact of nutrition on lameness and claw health in cattle. Livestock Science. 156:71-87.

Lübbe K, Wielsch B, Bosse I, Bahramsoltani M, Mülling Ch KW. 2016. Claw Horn Disruption: An In Vitro Study Of Early Pathomechanisms. Proceedings of 19th International Lameness Symposium. Munich.

Maas, J., L. E. Davis, C. Hempstead, J. N. Berg, and K. A. Hoffman. 1984. Efficacy of ethylenediamine dihydroiodide in the prevention of naturally occurring footrot in cattle. Am. J. Vet. Res. 45:2347.

Miller, J. K., N. Ramsey, and F. C. Madsen. 1988. The trace minerals in The Ruminant Animal. D. C. Church, ed. Pp. 342-400. Prentice Hall, Englewood Cliffs, NJ.

Moore, C. L., P. M. Walker, and J. R. Winter. 1989. Zinc supplementation for dairy cows. Trans. Ill. Acad. Sci. 82:99-108.

Nocek, J. E. 1997. Bovine acidosis: Implications on laminitis. J. Dairy Sci. 80:1005-1028.

Offer, J. E., G. E. J. Fisher, S. A. Kempson, and D. N. Logue. 2001. The effect of feeding grass silage in early pregnancy on claw health during first lactation. Vet. J. 161:186-193

Offer, J. E., K. A. Leach, S. Brocklehurst, and D. N. Logue. 2003. Effect of forage type on claw horn lesion development in dairy heifers. Vet. J. 165:221-227.

Pötzsch, C. J., V. J. Collis (née Hedges), R. W. Blowey, A. J. Packington, and L. E. Green. 2003. The impact of parity and duration of biotin supplementation on white line disease lameness in dairy cattle. J. Dairy Sci. 86:2577-2582.

Schwab, E. C., C. G. Schwab, R. D. Shaver, C. L. Girard, D. E. Putnam, and N. L. Whitehouse. 2006. Dietary forage and nonfiber carbohydrate contents influence b-vitamin intake, duodenal flow, and apparent ruminal synthesis in lactating dairy cows. J. Dairy Sci. 89:174-187.

Siciliano-Jones, J. L., M. T. Socha, D. J. Tomlinson, and J. M. DeFrain. 2008. Effect of trace mineral source on lactation performance, claw integrity, and fertility of dairy cattle. J. Dairy Sci. 91:1985-1995.

Tomlinson, D. J., C. H. Mülling, and T. M. Fakler. 2004. Invited review: Formation of keratins in the bovine claw: Roles of hormones, minerals, and vitamins in functional claw integrity. J. Dairy Sci. 87:797-809.

Van Eps, A. W. and C. C. Pollitt. 2006. Equine laminitis induced with oligo-fructose. Equine Vet. J. 38:203-208.

Woeber, K. A. and S. H. Ingbar. 1972. Metabolism of L-thyroxine by phagocytosing human leukocytes.

Xu, T., F. C. Cardoso, A. Pineda, E. Trevisi, X. Shen, F. Rosa, J. S. Osorio, and J. J. Loor. 2017. Grain challenge affects systemic and hepatic molecular biomarkers of inflammation, stress, and metabolic responses to a greater extent in Holstein than Jersey cows. J. Dairy Sci. 100:9153-9162.

Spot treatment, not pit treatment: Evaluating claw contact time of a spray product under field conditions

Roijackers DDJAM[1], Lammers G[1], Kloosterman P

[1] Intracare B.V., Veghel, The Netherlands

Email: droijackers@intracare.nl

Introduction

Lameness in dairy cattle has a major impact on health, welfare and production. This makes it one of the most important endemic diseases in dairy cattle (Huxley, 2013). Dairy farmers traditionally use foot baths to prevent hoof problems. However, the efficacy of footbaths is debatable as it depends on the transfer of the topical antibacterial agent to the foot and its contact time with the claw and adjacent skin (Cook et al., 2012). After a certain number of passages, footbaths are heavily polluted by manure. Because lame cows have the slowest walking speed, they will often pass through a polluted footbath. Additionally, a large part of the footbath content is spilled out of the bath and is thereby not reaching the correct spot on the feet of the cows. Eventually, the remaining chemical in the footbath is poured into the pit, which may contribute to ecotoxicological problems (Holzhauer et al., 2012). A new ready-to-use spray (Intra Hoof-fit Spray) allows every cow to be treated with fresh product regardless of their walking speed. The product can be used in the prevention of hoof problems and is based on equal parts of chelated copper and chelated zinc. It can be applied using e.g. a low-pressure sprayer, automatic sprayer or robot sprayer, and has a strong adhesive power to the claws providing a long contact time, which was evaluated in this trial under field conditions.

Materials and Methods

This study was performed on a Dutch dairy farm with 92 dairy cows. The disinfection protocol of this dairy farm did not include foot bathing. The feet of 6 dairy cows were sprayed (t=0) for 2 seconds using a low pressure sprayer, while the animals were secured to the feeding fence. Swabs from the feet were taken on 3 time points (t=1, t=3 and t=6 hours) while the animals were in a claw trimming box, and the last swabs were taken on the 4^{th} time point (t=9 hours) in the milking parlor. In between measuring moments, the cows were able to express their natural behavior under regular farm conditions in the house. Swabs were taken by a standardized method with a cotton swab and contained in a tube filled with 10 ml demineralized water. The samples were filtered over a 0.45 µm filter and the presence of copper was measured at a wavelength of 510 nm with a 4210 MP Atomic Emission Spectroscopy (AES) from Agilent Technologies. From an analytical point of view, copper was measured instead of zinc. Results were corrected for the average weight of the samples.

Results

In all samples at all measurement points copper was present on the feet of the cattle. The results from the AES analysis are shown as boxplots in figure 1.

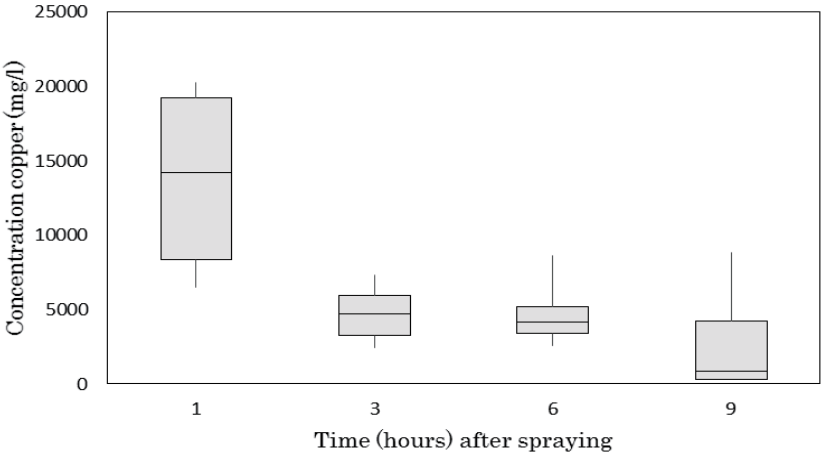


Figure 1. The concentration of copper (mg/l) present on the feet of 6 dairy cows at 4 different time points shown in boxplots. The boxplots show the minimum, 25% percentile, median, 75% percentile and maximum values.

Discussion and conclusions

The results show that at 4 different time points copper was still present on all feet. Even though the concentration decreased as expected because the cows were housed under regular farm conditions, it was still clearly present after 3 and 6 hours, at which the median of the boxplots was similar. After 9 hours, a relatively high copper concentration was observed in 2 cows. On the feet of the other cows copper was still present at lower concentrations, as shown by the boxplot at t=9 hours. The copper concentrations measured with the AES were influenced by multiple factors, including taking the swabs (taking swabs in the milking parlor was more challenging than in the claw trimming box, over time the feet got dirtier, and more manure was present on the swab), the behavior the cow expressed in-between measuring points (laying down, manure over the feet in the claw trimming box) and the anatomy of the cow. Because copper and zinc are present in equal concentrations in the product, identical concentrations of zinc are expected to be present at the different time points on the feet of the cattle. The long contact time provides copper to disinfect and protect the feet from new pathogenic bacteria, while simultaneously zinc stimulates skin regeneration.

This field trial demonstrates that a long contact time can be achieved by spraying the feet of cattle with a product that adheres firmly to the hooves, and can thereby disinfect, protect and stimulate skin regeneration. Overall, less product is required when feet are sprayed individually compared to foot bathing and no excess product is poured into the pit, which is both from an economical as ecotoxicological perspective beneficial.

Acknowledgements

We would like to thank the dairy farmer and his family for their hospitality during our trial.

References

Cook, N. B., Rieman, J., Gomez, A., & Burgi, K. (2012). Observations on the design and use of footbaths for the control of infectious hoof disease in dairy cattle. The veterinary journal, 193(3), 669-673.

Holzhauer, M., Bartels, C. J., Bergsten, C., van Riet, M. M., Frankena, K., & Lam, T. J. G. M. (2012). The effect of an acidified, ionized copper sulphate solution on digital dermatitis in dairy cows. The veterinary journal, 193(3), 659-663.

Huxley, J. N. (2013). Impact of lameness and claw lesions in cows on health and production. Livestock Science, 156(1-3), 64-70.

Pilot study to assess moisture content of dressings with different cattle foot bandaging techniques

Sophie Mahendran [1*]

Roger Blowey, Gloucester Vet Cons Ltd [2]

Dr Nick J. Bell [3]

Introduction

The style and duration of foot bandaging vary considerably in investigations of digital dermatitis treatment. Bandages are used to maintain topical treatments on the lesion, and keep lesions clean and dry. However, if applied incorrectly or for too long, there could be a risk of injury and worsening of lesions.
Seven-day bandages were reported to improve cure rate compared with no bandage in a recent German trial (Klawitter et al., 2017). However, the bandage method is more complicated than traditional bandage techniques and could become wet and deleterious to recovery under UK conditions, which typically involve regular foot baths and periods at grass. Hoof bandage guidance in the UK is often stated as an application for no more than 2 days (if a bandage is applied at all). It is also acknowledged that bandage application and removal must be quick and easy to reflect what is practical for trimmers and producers in the field.

The purpose of this pilot study was to determine if there is any difference in the moisture content of gauze dressings and skin health in cows receiving four different foot bandage styles applied over a 2 day versus 7-day duration. This pilot study aimed to generate informative qualitative observations as to the most appropriate bandaging style to use for future trials.

Materials and methods

A single dairy farm in the South of the UK was recruited in October 2018. The farm had 270 HF cows, housed at grass during the day, and in deep sand bedded cubicles at night. The farm used 4% formalin footbathing twice weekly for all milking cows, including those enrolled in the trial (footbathed on day 1 and day 5). Eight cows were enrolled onto the study, all with signs of visible non-regressing digital dermatitis lesions on one of their hind feet.

On enrolment, the cattle had both of their feet raised in a crush, according to best clinical practice. All cows received approximately 5g of Provita Hoofsure Konquest (Provita, NI) applied directly to a clean, dry, mildly debrided lesion with 2 sheets of standard large gauze swabs (10X10cm, 8 ply, Shermond UK), taking care not to apply the product to surrounding skin.

1.University of Surrey; 2. Wood Vet Group, Gloucester; 3 Bos International Ltd *Lead author

1. s.a.mahendran8@gmail.com 2. rogerblowey@hotmail.com 3. herdhealth@gmail.com

Four different bandage designs were tested, with two cows randomly (block) allocated to each of the following bandage groups;
I. High (above dew claw) cohesive bandage (10cm X 4.5m, Bodhi & Digby, UK) with conforming bandage (10cm X 4.5m, Knitfirm, Millpledge UK).

II. Low cohesive bandage (below dew claws) with conforming bandage

III. Low cohesive bandage loosely applied without conforming bandage (2-fingers passing under bandage)

IV. Low cohesive bandage loosely applied without conforming bandage, with a tape to seal the top

Within each group one cow had the bandage removed after 2 days, and the other cow had the bandage removed after 7 days.

1.University of Surrey; 2. Wood Vet Group, Gloucester; 3 Bos International Ltd *Lead author

1. s.a.mahendran8@gmail.com 2. rogerblowey@hotmail.com 3. herdhealth@gmail.com

Lesions were photographed on day 0 (recruitment), and again at day 7.
The whole bandage was weighed at removal, dried in an oven at 60^{o}c for 6 hours and re-weighed. Skin condition and lesion appearance will be evaluated by M-score (Berry et al 2012) and also qualitatively described.

1.University of Surrey; 2. Wood Vet Group, Gloucester; 3 Bos International Ltd *Lead author

1. s.a.mahendran8@gmail.com 2. rogerblowey@hotmail.com 3. herdhealth@gmail.com

Results and Discussion

Cow	Bandage group	Initial weight (g)	Post-drying weight (g)	Change in weight (g)	Change in weight (g) after correction for Konquest moisture	Corrected moisture content of bandage %
1	Low, cohesive bandage, 2 day	60	41	19	11	18%
2	Low, conforming, cohesive bandage, 2 day	223	117	116	108	48%
3	Low, cohesive bandage, tape seal, 2 day	66	51	15	7	11%
4	High conforming and cohesive bandage, 2 day	175	102	73	65	37%
5	Low, cohesive bandage. 7 day	82	59	23	15	18%
6	Low with conforming, cohesive bandage, 7 day	234	126	108	100	43%
7	Low, cohesive bandage tape seal, 7 day	101	70	31	23	23%
8	High, conforming, cohesive bandage, 7 day	251	147	104	96	38%

1.University of Surrey; 2. Wood Vet Group, Gloucester; 3 Bos International Ltd *Lead author

1. s.a.mahendran8@gmail.com 2. rogerblowey@hotmail.com 3. herdhealth@gmail.com

Figure 1: example of the digital dermatitis lesions at day 7 post treatment application.

The gauze swabs weighed 3g and had no measurable change in dry matter found when dried in the oven. A test swab with a 10g application of the Konquest gel (a treatment dose) was also assessed for dry matter. Prior to drying, the combined swab and gel weighed 13g. After drying, the swabs and residual gel weighed 5g. This indicates that the swabs contributed approximately 8g of moisture to the bandage dressing.

Removal of the bandages containing a conforming layer proved to be difficult within the parlour. The conforming layer was difficult to cut without the leg being restrained, thus reducing its ease of use in the field.

On removal of all bandages, there was green colouring present on the swab and skin, but no visible Konquest gel. This indicates that the gel had either been absorbed into the lesion, or into the swabs covering the lesion. The skin underneath all of the bandages, and the inside of the bandage material was moist to the touch, especially under the bandages that contained a conforming layer. There was evidence of moisture maceration around the coronary band of the cattle. One cow developed interdigital necrobacillosis three days after bandage removal (high bandage with conforming layer and cohesive bandage on for 2 days).

The swabs that were placed directly onto the skin without a conforming layer underneath the cohesive bandage had moisture content between a 11-23% moisture content before drying after correcting for moisture from the treatment..

1.University of Surrey; 2. Wood Vet Group, Gloucester; 3 Bos International Ltd *Lead author

1. s.a.mahendran8@gmail.com 2. rogerblowey@hotmail.com 3. herdhealth@gmail.com

The bandages containing a conforming layer had moisture levels between 37-48%, consistently higher than the bandages without the conforming layer. This could be potentially due to the increased absorbance capacity of this extra layer, which may have retained moisture from the environment and foot bath.

Scoring of the lesions was possible with the foot hosed off in the parlour. The lesions were initially scored as M4 lesions, but with areas of pink tissue where the salicylic acid had eroded the keratotic lesion (Figure 1). On bandage removal (day 2 or day 7), the lesions were still M4. The cows were observed 3 months after the digital dermatitis treatment in this trial, and all lesions were still visible, with an M4 score. Measurement of the lesions was not made in this study, but the author noted that the lesions did appear smaller in size for all treatments when photographs were compared.

Conclusions

Environmental moisture is likely to be harmful to wound recovery, particularly if contaminated by foot bath biocide. In this study we could not determine with any certainty how much moisture was derived from the animal (integument) and how much was environmental in origin, but it would seem likely the environment is the primary source of moisture, especially given the cohesive bandage is porous and breathable. The comparison of a 2 day and 7-day bandage showed they are both likely become moist in the absence of a waterproofing external layer, and further work is needed to quantitatively test our observation that there is less moisture with a shorter application of bandage. This study has shown when a bandage is indicated for use in the treatment of digital dermatitis lesions when cattle are kept in environments with access to pasture and regular use of footbathing then waterproofing should be used or bandages removed after short durations. However, the need for bandages at all should be carefully considered given the risk of skin trauma and high moisture levels predisposing to development of interdigital skin lesions like interdigital necrobacillosis.

Acknowledgments

Thanks go to Provita Animal Health for funding this trial.

References

Berry et al 2012

Klawitter, M., Braden T, Müllerk E, 2017. To Bandage Or Not Bandage: The Curative Effect Of Bandaging Digital Dermatitis Lesions, in: 19th International Symposium and 11th Conference on Lameness in Ruminants. Munich, pp. 48–49.

1.University of Surrey; 2. Wood Vet Group, Gloucester; 3 Bos International Ltd *Lead author

1. s.a.mahendran8@gmail.com 2. rogerblowey@hotmail.com 3. herdhealth@gmail.com

Histological comparison of the effect of antibiotic and non-antibiotic topical treatments for digital dermatitis on treponemes and the tissue regeneration

Charlotte Kroeger[1,3,*], Doerte Doepfer[2], Andrea Fiedler[3], Christoph Muelling[4], Eva Zeiler[5], Johann Maierl[1]

Introduction

Digital dermatitis (DD) is an international problem on beef and dairy farms and predominantly caused by *Treponema spp*. (CORNELISSE et al., 1997; WILSON-WELDER et al., 2015). This most important infectious claw disease in cattle leads to damaged and infected skin with erosive and painful lesions (CUTLER et al., 2013; READ und WALKER, 1998). The typical defect is located on the hind legs at the coronary band. Due to the high number of infected animals, a lot of drugs are used for treatment and prevention. After topical treatment is judged as effective by positive clinical evaluation, many relapses occur throughout the herds, supposedly caused by encysted Treponema in the epidermal layers and bad environmental hygiene. The histology of affected skin shows a varying shallow deterioration of the *stratum corneum* to a deep disruption of the *stratum basale* down into the dermis (BERRY et al., 2010). To reduce the amount of dispensed drugs it is necessary to understand wound closure and the healing process following topical treatment of DD lesions, to enhance a better long term effect.

Materials and Methods

A total of 100 cows out of 5 commercial dairy farms in Bavaria were included in the study. Every cow was scored at least 6 months prior to the start of the study to group the cows into type 1-3 cows. A modified DD lesion score was used to evaluate the feet. Every cow with an M2-lesion greater than 2 cm in diameter and a scoring history was trimmed on day zero and randomly assigned to one of the 5 different treatment groups. The biopsies (ø 6 mm) were taken under local anesthesia and the cows were treated with an NSAID to avoid any additional pain. Skin punch biopsies and photographs were taken on day 0, day 14 and day 28 from the lesions. The topical treatments include the single usage or combination of chlortetracycline, zinc- and copper chelates, a polyurethane wound dressing or salicylic acid. Every M2-lesion was wrapped after the treatment. From each biopsy a 4 µm thick sample was stained with hematoxylin and eosin to analyze the layers of the affected skin. Every sample was evaluated in 13 different categories looking at the integrity, the thickness and continuity of the *stratum corneum, stratum granulosum* together with the *stratum spinosum* and *stratum basale*. In addition, signs of inflammation, perivascular infiltration and mitotic activity were scored as normal or high.

The experimental set up was evaluated and accepted by the District Government of Upper Bavaria and the number of approval is NTP-ID: 00007101-1-3.

Results

All 5 different treatments show the potential of a positive clinical outcome of the treated lesions but the success of the treatments deviate obviously between the groups. The histological evaluations present different reactions of the epidermal layers depending on the treatment. The samples of the polyurethane wound dressing show a restructuring of the *stratum profundum* with long papillary bodies under a thin, orthokeratotic stratum corneum. When it comes to wound closure of the M2-lesion after topical treatment

[1] Chair of Anatomy, Histology and Embryology, Department of Veterinary Sciences, Ludwig-Maximilian University Munich, Germany
[2] School of Veterinary Medicine, University of Wisconsin, Madison, USA
[3] Praxisgemeinschaft fuer Klauengesundheit, Munich, Germany
[4] Institute of Veterinary Anatomy, Leipzig, Germany
[5] Weihenstephan-Triesdorf, University of Applied Sciences, Freising, Germany
* E-Mail: c.p.kroeger@web.de

with chlortetracycline, salicylic acid or zinc- and copper-chelates, wound closure results a moderate or massive hyper- or parakeratosis of the *stratum corneum*. The thick, dyskeratotic *stratum profundum* shows only short papillary bodies. From day 14 to day 28 most of the thickened *stratum corneum* is lost.

Conclusions

By comparing the treatment groups, it is obvious, that also antibiotic-free treatments have the possibility to result in improved healing of DD lesions and such treatment agents can lead to wound closure with a minimum or no detectable pain. The understanding of the epidermal reaction to topical treatment is fundamental to the care of the resulting tissue with particular regards to foot bathing or other preventive interventions such as management tools.

Acknowledge

We acknowledge the District Government of Upper Bavaria (StMELF) for funding this study and want to thank the farmers, the hoof trimmers and the people working in the laboratory for their sedulous work.

References

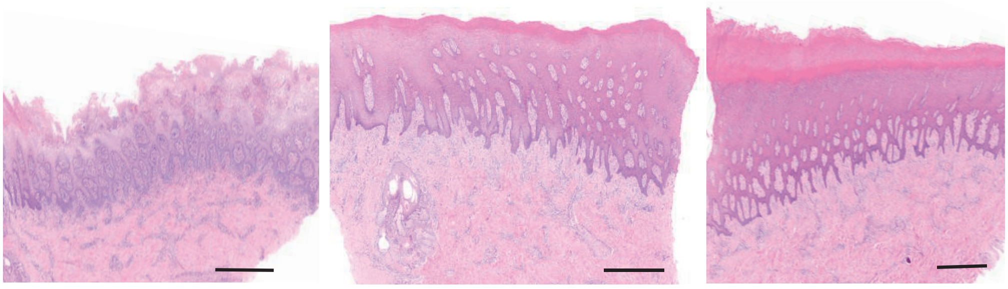
1 Berry, S. L., Read, D. H., Walker, R. L. und Famula, T. R. (2010): Clinical, histologic, and bacteriologic findings in dairy cows with digital dermatitis (footwarts) one month after topical treatment with lincomycin hydrochloride or oxytetracycline hydrochloride. Journal of the American Veterinary Medical Association 237(5): 555-560.

2 Cornelisse, J., van Asten, A. und ter Huurne, A. (1997): Histological and bacteriological evaluation of digital dermatitis in cattle, with special reference to spirochaetes and Campylobacter faecalis. The veterinary record 140: 620-623.

3 Cutler, J. H., Cramer, G., Walter, J., Millman, S. und Kelton, D. (2013): Randomized clinical trial of tetracycline hydrochloride bandage and paste treatments for resolution of lesions and pain associated with digital dermatitis in dairy cattle. Journal of dairy science 96(12): 7550-7557.

4 Read, D. H. und Walker, R. L. (1998): Papillomatous digital dermatitis (footwarts) in California dairy cattle: clinical and gross pathologic findings. Journal of Veterinary Diagnostic Investigation 10(1): 67-76.

5 Wilson-Welder, J. H., Alt, D. P. und Nally, J. E. (2015): Digital Dermatitis in Cattle: Current Bacterial and Immunological Findings. Animals 5(4): 1114-1135.



day 0 day 14 day 28

Figure 1: Example of a positive development of the epidermal layers after a topical treatment of an M2-lesion of one cow from day 0 over day 14 until day 28, the bar in the HE-stained samples equals 1 mm, **day 0:** loss of the stratum corneum, massive deterioration of the stratum granulosum and stratum spinosum down to the stratum basale; **day 14:** homogeneous stratum corneum covers the wound, stratum profundum is thickened and asymmetric, stratum basale is intact; **day 28:** stratum corneum intact, deep regeneration of the epidermis and papillary dermis.

Combination Effect of Allyl Isothiocyanate and Hoof Trimming on Bovine Digital Dermatitis

Hiroyuki MANABE[2], Takumi YAMAMOTO[1], Naoaki MISAWA[3], Wataru YAMAZAKI[3], Masahiro TAKAHASHI[1] and Keiji OKADA[1]

Introduction

Digital Dermatitis is a localized infectious dermatitis caused by Treponema- like spirochetes. Antibiotics, such as lincomycin, are currently used for treatment, but their use imposes a withdrawal period. This study investigated the therapeutic effect of topical application of the natural component allyl isothiocyanate, in combination with maintenance hoof trimming, on bovine Digital Dermatitis (stage M2 DD lesions based on Döpfer classification).

Materials and Methods

Study cows were divided into two groups, the Trimming Group and Non-Trimming Group. The day when allyl isothiocyanate was applied, along with hoof trimming, was set as Day 0. Lesion scores, pain, and the presence of Treponema-like spirochetes on the surface of hooves and in biopsy samples of the tissues were evaluated until Day 6. Assessment of pain was based on a Force Gauge when applying pressure to the lesion.

Results

One of the microscopic observations of direct smear specimens to detect spirochetes is shown in Fig. 1. These long and coiledstained microorganisms are likely *Treponema*-like spirochetes related with the DD. On the surface of the lesions in the Trimming Group, the percentage of *Treponema*-like spirochete positive cows was 83.3% on Day 0, but spirochetes were not detected from Day 2 onward. On the surface of the lesions in the Non-Trimming Group, the percentage of Treponema-like spirochete positive cows was 87.5% on Day 0, but decreased to 25.0% on Day 2 and 12.5% on Day 4. On Day 6, it was 50%, which was significantly higher than it was on Day 4. In addition, the percentage of positive cows in the Trimming Group was significantly lower than that in the Non-Trimming Group on Day 6 (Table 1).

Both groups showed improvement of lesion scores. And photos of the DD stained with Warthin-Starry show numerous Treponema-like spirochetes that were detected in the keratin layer on Day 0 (Fig. 2), but were not detectable in any of the cows on Day 6 (Fig. 3) in both groups. On the surface of the interdigital clefts in the Trimming Group, the percentage of Treponema-like spirochete positive cows was 16.7% on Day 0, 0% on Day 2 and Day 4, and 16.7% on Day 6, which were not significant changes. In the Non-Trimming Group, the percentage of Treponema-like spirochete positive cows was 37.5% on Day 0 and 50.0% on Day 2. On Day 4 and Day 6, the percentage was 0%, which was significantly lower than the percentage on Day 2. Additionally, the percentage of positive cows in the Trimming Group was significantly lower in the Non-Trimming Group on Day 2 (Table 2).

Conclusions

These results suggest that allyl isothiocyanate has therapeutic effects on Digital Dermatitis, when combined with hoof trimming, and may prevent a relapse of dermatitis and a re-infection of Treponema-like spirochetes.

Acknowledge (if needed)

This study was funded by Mitsubishi-Chemical Foods Corporation.

- [1] Cooperative Department of Veterinary Medicine, Faculty of Agriculture, Iwate
- University, Japan
- [2] MH Limited, Japan
- [3] Department of Veterinary Science, Faculty of Agriculture, University of Miyazaki, Japan
- * E-mail: keiji@iwate-u.ac.jp

	Day 0	Day 2	Day 4	Day 6
Trimming Group	83.3	0 a	0 a	0 a
Non-Trimming Group	87.5	25.0	12.5 b	50.0 *

Table 1 **Detection Rate of Treponema-Like Spirochetes on The Surface of Lesions (%)**
Detection rate of Treponema-like spirochetes on the surface of lesions in the Trimming Group (n=6) and in the Non-Trimming Group (n=8). Letters "a" and "b" indicate a significant difference from Day 0 within the same group. The "＊" indicates a significant difference between the groups on the same sampling date. Treponema-like spirochetes were not detectable on the surface of lesions after Day 2 in the Trimming Group.

	Day 0	Day 2	Day 4	Day 6
Trimming Group	16.7	0	0	16.7
Non-Trimming Group	37.5	50 *	0 a	0 a

Table 2 **Detection Rate of Treponema-Like Spirochetes on The Skin of Interdigital Clefts (%)**
Detection rate of Treponema-like spirochetes on the skin of the interdigital clefts in the Trimming Group (n=6) and in the Non-Trimming group (n=8). The letter "a" represents a significant difference from Day 2 in the Non-Trimming group. The "*" indicates a significant difference between the groups on the same sampling date. Treponema-like spirochetes were not detectable on the skin of interdigital clefts after Day 2 in the Trimming Group and after Day 4 in the Non-Trimming Group.

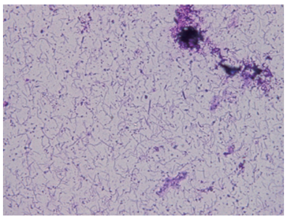


Fig. 1 Treponema**-like spirochetes in a direct smear specimen stained with Giemsa**

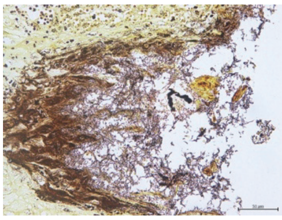


Fig. 2 **Keratin layer on Day 0**

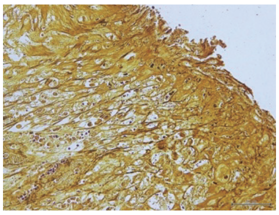


Fig. 3. **Keratin layer on Day 6**

Therapeutic effect in topical applications of acrinol to digital dermatitis in milking cows

Masanori Ito[1,*]

Introduction

Digital dermatitis (DD) is infectious inflammation involving the digital skin. Treponemas are the possible causative bacteria, and have the high infectious capacity between cows, and between farms. In cows with severe DDs, the cauliflower-like or papillary lesions are formed within the inter-digital space and the palmar skins, resulting in severe pain and lameness. Topical applications of antibiotics (especially, oxytetracycline [OTC]) are the common and effective therapy for DD. However, treatment of DD without antibiotics is recently recommended in worldwide trends of "one health". The aim of this study is to evaluate the therapeutic effect of acrinol (a disinfectant material for external use) in the topical applications to the DD lesions by comparison with that of OTC.

Materials and Methods

Experimental group: The animals were 107 Holstein milking cows kept in 14 dairy farms, in which the DD lesions have been found within 155 claws between April 2016 and March 2018. An acrinol powder (Acrinol[KozakaiM],Kozakaiseiyaku,Tokyo,Japan) was applied to 82 claws of 53 animals with dose of 2-4 grams per a lesion (dependent on the sizes of the lesions), sprinkled on 5-8 grams of a pine tar ointment(Teibyounankou,Nihonzenyaku,Fukusima,Japan) (for a bonding agent) between April 2016 and March 2017 (acrinol-pine-tar group). Between April 2017 and March 2018, 73 claws of 54 animals were treated with 5-10 grams of an acrinol-containing petrolatum ointment, in which an acrinol powder was contained 20% or 30% of the total weight (acrinol-petrolatum group). OTC group: An OTC injectable medicine 5-7 ml (OTCchuu10%[Fujita],Fjitaseiyaku,Tokyo,Japan) was topically applied to 59 claws of 39 animals between April 2015 and April 2016. In the treatments, trimming and cleaning lesions were followed by topical applications of each these 3 material; the cotton wools, on which the materials were placed, were applied to the DD lesions, and wrapped with elastic bandage. The bandages were exchanged at about 10 days intervals. In the exchanges, "healing" was detected by observations of normal skin structures, when the scab-like structures (formed in recovery process) were removed. The numbers of treatment were statistically compared among 3 groups using a Steel-Dwass method.

Results

All 155 DD lesions were cured by topical applications of both acrinol-pine-tar-ointment and acrinol-petrolatum ointment. The numbers of treatment were 3.3±1.0 (n=82), 2.7±0.8 (n=73), and 3.1±1.0 (n=59) in acrinol-pine-tar, acrinol-petrolatum, and OTC groups, respectively. Number of treatment in acrinol-petrolatum group tended to be lower than that in OTC group. Significantly ($p<0.01$) lower number of treatment was found between acrinol-pine-tar and acrinol-petrolatum groups.

Conclusions

Uses of acrinol enabled intact healing in all DD lesions, although increased numbers of treatment was associated with the larger sizes of DD lesions. Significantly lower number of treatment in acrinol-petrolatum group than acrinol-pine-tar group may be explainable by the higher permeability and adhesiveness to the DD lesions in topical uses of acrinol-containing petrolatum ointment, in which particles of acrinol were dispersed throughout. This study indicates that acrinol-containing petrolatum ointment is equal to OTC injectable medicine for clinical utilization in topical treatment of the DD lesions in milking cows, based on no difference between these 2 therapeutic agents in the numbers of treatment.

[1] Kanagawa Prefectural Federation Agricultural Mutual Aid Association, Isehara, Kanagawa, Japan
* E-mail: masadoka-730302@mb.scn-net.ne.jp

Study on the performance of a spray foam containing elementary silver for the supportive care of digitalis dermatitis

Andrea Fiedler[1]*, Charlotte Kröger[1] and Katharina Grimm[1]

Introduction

The increase in the prevalence of digital dermatitis (DD) in dairy cows over the past decades (Fiedler, 2000; Holzhauer et al., 2006; Cramer et al., 2008) makes a targeted control of this disease necessary. In the acute stage, digital dermatitis can lead to painful dermatitis lesions (Laven and Logue, 2006), causing severe lameness. A reduction in milk yield, an extension of the gestation period and the time and cost of targeted treatments are only a few factors that impair the economic performance of the animals in the event of lameness.Losses can add up to 600 Euros per cow (Bilcalho et al., 2008; Mülling and Hagen, 2012). While treatment of individual animals is common, for skin care sustainable caring products can be applied on a regular basis between the hoof trimming appointments in order to keep the skin surface healthy and to stabilize the status of DD in the herd.

The aim of this study was to investigate if the regular use of a hoof care product containing pure elementary silver (MicroSilver BG) could reduce the recurrence rate of digital dermatitis in a dairy herd..

Materials and Methods

The study herd was an organic dairy herd, located in Germany, including Holstein-Friesian cows, Red Holstein cows, German Simmental cattle, Brown Swiss and various crosses.

On day -6 a total of 127 dairy cows were trimmed, existing lesions documented according to a modified documentation scheme according to Döpfer (1994) and treated according to the following protocol: tetracycline spray under bandage for 3 days - M1; salicylic acid under bandage for 6 days - M2, M3, M4, M4.1. On day 0, a second evaluation took place after removing all bandages and the study began. During the study period, all hind feet were washed in the milking parlour with water once a day before milking. After milking, the product was only applied to the right feet (test group), the left feet represented the control group. Animals treated with systemic antibiotics during the trial phase were excluded.

Further evaluations took place on days 28, 56, 84 and 116. At the day of the last examination, 101 animals remained in the experiment. Following day 116 the animals did not receive further treatment with the test product for 180 additional days and all feet were examined again afterwards.

Results

There was no irritation of the treated skin areas during the trial. In the beginning the mean score of left feet (control) and right feet (test) were 3.56 compared to 3.7. On day 0 the control group showed a lower sum of scores (223, mean score 2) than the test group (475, mean score 3.28). During the trial the test group remained stable, while the control group showed an increasing mean score (Fig. 1). After further 180 days without any product on both feet the mean scores have converged again (control: 7.88; test 9.3), showing a general increase.

Conclusions

Compared to untreated feet, the MicroSilver BG containing product stabilized the status of the hooves and significantly reduced the relapse rate in DD.

[1] Praxisgemeinschaft für Klauengesundheit / Hoof Health Associates, Munich, Germany
* E-mail: info@praxis-klauengesundheit.de

Acknowledge

Many thanks to the trimmers and students supporting the evaluation and to Biogate, Germany, for their funding support.

References

Cramer, G., K. D. Lissemore, C. L. Guard, K. E. Leslie, and D. F. Kelton (2008): Herd- and cow-level prevalence of foot lesions in Ontario dairy cattle. J. Dairy Sci. 91:3888-3895.

Laven, R. A. and D. N. Logue (2006): Treatment strategies for digital dermatitis for the UK. Vet. J. 171:79–88.

Holzhauer, M., C. Hardenberg, C. J. M. Bartels and K. Frankena (2006): Herd- and cow-level prevalence of digital dermatitis in the Netherlands and associated risk factors. J. Dairy Sci. 89:580–588.

Bilcalho, R.C., L.D. Warnick, C.L. Guard (2008): Strategies to analyze milk losses caused by diseases with potential incidence throughout the lactation: A lameness example. J. Dairy Sci. 91: 2653-2661.

Döpfer D. (1994): Epidemiological investigations of digital dermatitis on two dairy farms. Thesis, Hannover, Germany.

Fiedler A. (2000) Comparative studies about the prevalence of claw diseases in tie-stalls and loose-housing systems in Bavaria 1998 and 1999. In: Proc.11th Int. Symp. Disorders of the Ruminant Digit, Parma, Italy, 3-7 September 2000, 157-159.

Mülling C., J. Hagen (2012): Bedeutung von Klauenerkrankungen und funktionelle Anatomie der Klaue. Der prakt. Tierarzt 93 (Suppl. 1) 4-10.

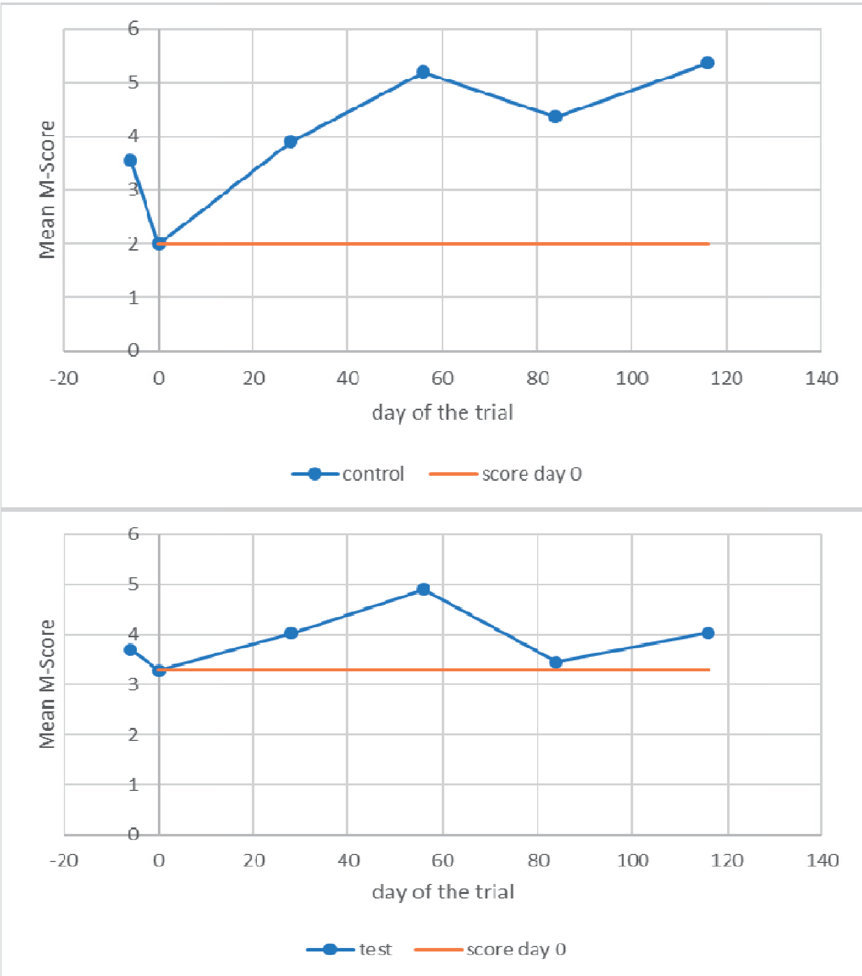


Figure 1: development of mean score of control and test group, compared to mean score on day 0.

appearance/finding	score
M1 (without pain)	1 - 3
M2 (with pain)	30 - 60
M3	4 - 6
M4	7 - 9
M4.1	20
M0	0

Table 1: Score (modified, Doepfer, 1994)

	M1	M2	M3	M4
right hind (treated with product, TEST GROUP)	53	3	0	19
%	52.5%	3%	0%	18.8%
left hind (without product, CONTROL GROUP)	57	7	0	16
%	56.4%	6.9%	0%	15.8%

Table 2: numbers of M-stages on day 116 in control and test group (101 cows).

	M1	M2	M3	M4
right hind (without product)	19	12	0	9
%	23.5%	14.8%	0%	11.1%
left hind (without product)	28	9	0	8
%	34.6%	11.1%	0	9.9%

Table 3: numbers of M-stages after 180 days without product in control and test group (81 cows).

Figure 1: DD stages M0, M1 and M4

How to trim the forelimb claws – claw loads with different sole heights

Karl Nuss, Judith Müller, Isabelle Lüchinger[1]

Introduction
The emphasis of claw trimming textbooks and practical claw trimming courses is on trimming the hind limb claws. Forelimb claws are rarely mentioned for two reasons: Firstly, the prevalence of claw horn lesions is much lower in the forelimbs than in the hind limbs, and secondly, not much is known about the biomechanics and thus proper functional trimming of the forelimb claws. Therefore, the aim of our study was to determine loading of the front limbs claws and to examine the effect of two different trimming procedures on functional offloading of the medial claw.

Materials and Methods
The vertical ground reaction forces (vGRFs) exerted on the forelimb claws were measured in 30 non-lame dairy cows during square standing. Three different situations were created and evaluated: The claws were trimmed to the same sole height (procedure 1); 3-mm wooden blocks were temporarily attached to both lateral claws (procedure 2), and then 3-mm wooden blocks were attached to both medial claws of the forelimbs (procedure 3) to simulate the effect of different sole heights.

Results
With even sole heights (procedure 1), a mean of 70% of the vGRF of the forelimbs was transferred to the medial claws. With a 3-mm wooden block attached to both lateral claws (procedure 2), the vGRF was evenly distributed between the lateral and medial claws. With procedure 3, a mean of 83% of the vGRF of the forelimbs was transferred to the medial claws.

Conclusions
In square-standing routinely trimmed cows, most of the vGRF acting on the forelimbs was exerted on the medial claws, which is in accordance with earlier studies (van der Tol et al. 2002, Cardona Gavaldon et al., 2015). To achieve even weight distribution between the lateral and medial claw of the forelimbs with functional trimming, the sole of the lateral claw should be left approximately 3 mm higher than that of the medial claw. A difference in height > 3 mm of the soles of may be necessary to achieve more load reduction in the medial claws.

Acknowledge
Thomas Wiestner and Laurent Hoffmann for technical advice during the measurements.

References
Van der Tol PP, Metz JH, Noordhuizen-Stassen EN, Back W, Braam CR, Weijs WA. The pressure distribution under the bovine claw during square standing on a flat substrate. J Dairy Sci. 2002;85(6):1476-81.

Cardona Gavaldon N., Wiestner T, Torgerson P, Nuss K. 2015. Force distribution between front and hind feet and between paired claws in lactating dairy cows standing on different surfaces. in: Tadich N, ed. Proc 18th Intern Symp and 10th Intern Conf Lameness in Ruminants, Valdivia, Chile. p. 99.

[1] Farm Animal Surgery Section, Vetsuisse Faculty University of Zürich, Switzerland
* E-mail: karl.nuss@uzh.ch

The effects of wooden blocks on load distribution in fore- and hind limb claws of dairy cows.

Karl Nuss*, Judith Müller, Isabelle Lüchinger[1]

Introduction

Application of blocks to treat claw horn lesions in dairy cows is a procedure commonly carried out by farmers, hoof trimmers, and veterinarians. Although the positive effects of this treatment have long been known (Nuss and Tiefenthaler, 2000, Wehrle et al., 2000), scientific studies have been done only recently (Thomas et al. 2015). Little is known about the effect of a wooden block on the limb it is attached to and the load distribution changes in the contralateral limb. Therefore, the aim of our study was to determine whether changes in weight distribution occur in the fore- and hind limbs of dairy cows after application of a wooden block.

Materials and Methods

A custom-made wooden block, 3 cm thick, was temporarily attached with duck tape to the lateral claw of the left forelimb in 30 dairy cows for the measurements. The load, consisting of vertical ground reaction force, sole imprint area, and mean and maximum pressure were measured simultaneously in both forelimbs. Data were acquired using a platform containing a force plate, which was connected to a pressure plate, an interface box, and a PC. The block was then removed and attached to the medial claw of the left hind limb, and the same variables were measured in the hind limbs.

Results

With a wooden block on the lateral claw of the left forelimb, there was a tendency for the cow to transfer weight to the right forelimb, but the mean ground reaction forces exerted on the limbs and claws measured before and after block application did not differ significantly. As expected, the load of the left forelimb was exclusively transferred to the claw to which the block was attached to. Similarly, with a wooden block on the medial claw of the left hind limb, there was a tendency for the cow to transfer the load to the right hind limb. The pressures, but not the mean ground reaction forces exerted on the limbs and claws measured before and after block application did differ significantly. However, the vertical ground reaction forces and pressures transferred to the bulbar zone of the lateral claw of the hind limb contralateral to the block increased significantly. Also, there were changes in load distribution in the lateral and medial claws of the contralateral hind limb.

Conclusions

A 3-cm wooden block fulfilled expectations in that it offloaded the partner claw. Within the 2-second measuring period, there was no significant transfer of load towards the contralateral limb. When we analysed the sole and bulbar zones of the claws separately, there were significant changes in the hind limb contralateral to the block. There, the vertical ground reaction forces and pressures transferred to the bulbar zone increased significantly. These findings indicate that a wooden block should be removed as soon as the claw lesion in the partner claw has healed to avoid increased loading of the claw with the wooden block and to avoid increased loading of the bulbar area of the contralateral lateral claw in the hind limbs.

---

[1] Farm Animal Surgery Section, Vetsuisse Faculty University of Zurich, Switzerland
* E-mail: karl.nuss@uzh.ch

Acknowledge

Luciano Schmid, Eva Weidmann, and Thomas Wiestner help with the planning and for construction of the platform, and assistance with the measurements.

References

1. Thomas HJ, Miguel-Pacheco GG, Bollard NJ, Archer SC, Bell NJ, Mason C, et al. Evaluation of treatments for claw horn lesions in dairy cows in a randomized controlled trial. J Dairy Sci. 2015;98(7):4477-86.
2. Nuss, K. and I. Tiefenthaler. 2000. Eigenschaften und klinische Anwendung gebräuchlicher Klauenkothurne [properties and clinical use of available claw blocks]. Tieraerztl Prax 28 (G):125-132.
3. Wehrle, M., C. Lischer, H. Geyer, R. Landerer, and M. Räber. 2000. Three different techniques of elevating an affected claw in comparison. Schweiz Arch Tierheilkde 142(9):507-511.

Determining Hoof Trimming Schedule Based on Various Management Factors

David W. Kammel[1], Karl Burgi[2], Jim Lewis[3], and Kimberly Evert[4]

1. Professor, Biological Systems Engineering University of Wisconsin,　Madison, WI USA
2. Owner, Sure Step Consulting International, LLC,　Baraboo, WI USA
3. Owner, Stepright Stockmanship Solutions, LLC,　Colfax, WI USA
4. Hoof Health Research Director, Sure Step Consulting International, LLC　Baraboo, WI USA

Introduction

Hoof trimming and footbath management are two main lameness preventative procedures implemented on dairy farms. Scheduled hoof trimming is a common practice of a lameness prevention management plan. With a good lameness prevention program and ideal conditions, it is estimated that it requires 2.2 to 2.5 trims per cow per year. Trims mean an assessment or inspection of the hooves and only remove extra horn when and where necessary. This study further investigates management factors that determine the number of hoof trims required per year.

Materials and Methods

Today we understand that if hoofs are not in good shape during parturition there is a higher risk for lameness onset 60 to 90 days later.　This is due to the many transformations that occur during the calving period including:

- inflammation occurrence
- hormonal changes
- enzyme alteration
- social and environmental adjustments

Timed hoof trimming is a scheduled trimming of the cow's hooves for lameness prevention at the optimal times such as the dry period.　In addition, it is not trimming cows during stressful periods like the closeup, fresh cow period, and peak lactation. Every good hoof health program starts with a scheduled trimming in the cow's far off dry period (60-22 days before calving) to prepare them for calving. It is not recommended to trim cows during the closeup period (21-0 days before calving) and early part of the lactation (0-80 days in milk). The next scheduled trim should occur after peak production. (100-180 days after first trim). Figure 1 shows a cow's reproductive cycle and time periods when trimming should or should not occur.

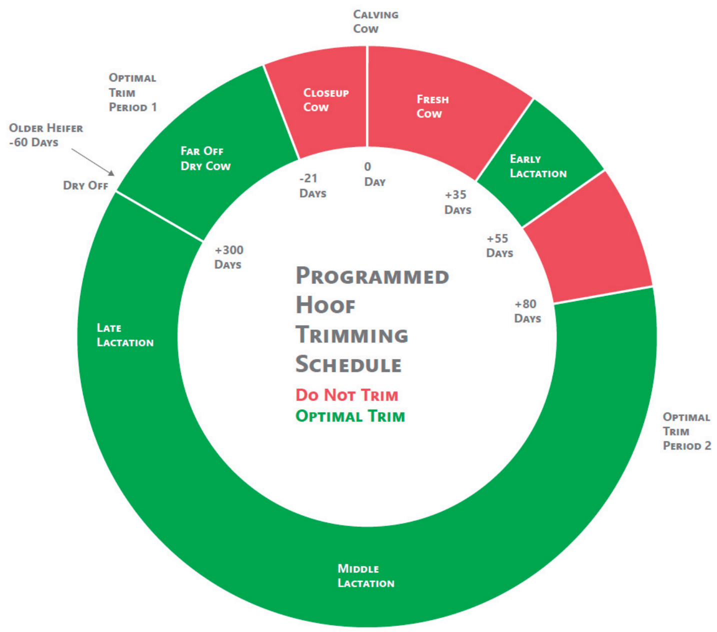


Figure 1.

There are many housing and management factors related to cow comfort that determine the need for hoof trimming needs and schedule for a specific dairy farm. The main factors are related to:

- Cow comfort
  - bedding type
    - sand
    - organic
  - floor surface
    - rubber
    - concrete
    - asphalt
    - slatted floor
  - floor slopes
  - 90 degree corners
  - freestall design and management
  - heat abatement design and management
- Cow time budgets
  - lying time
  - time forced away from the pen
  - headlock time
  - travel walking distance to parlor
  - milking frequency
- Management
  - stockmanship
  - stocking density
  - number of cows per pen

Grazing herds and cows housed on deep bedded freestall beds with sand or straw and lime have the lowest hoof trimming requirements. Deep bedded freestalls with other bedding material can have low requirements if flooring is optimal. An ideal trimming schedule for a healthy herd with optimal cow comfort conditions such as sand beds, good time budgets, would be a trim during the far off dry period and a mid-lactation trim at around 125 to 140 DIM. This is a schedule of every 150 to 180 days. In addition, there would be the trimming required for the normal occurring lame cows estimated to be 2.5 to 15 % of the herd per year.

Sand provides better traction, best cow comfort, and less trauma to the hoofs resulting in less horn growth. In many cases dairy herds from 400 to 1500 cows housed in sand bedded freestalls have less hoof wear and will require 2 trims per cow per year especially if the farm uses a fine sand similar to fracking sand or blow sand. In medium to large dairy herds with coarse or aggressive sand, the wear becomes too much and the need for preventative hoof trimming is reduced to one assessment of every cow per year and daily identification and treatment of lame cows. In such cases it is estimated that 1.2 to 1.5 assessments or trimmings per year is required. To be consistent in management 2 assessments per year is recommended. As the dairy herds increase in size hoof wear increases because of walking distance to and from the milking center. If the sand is coarse or consists of sharp sand particles, the wear of the hoofs increases.

On a dairy farm with mattress based freestalls using organic bedding, it is recommended to have 3 assessments per year. A trim at late dry period before closeup move, 80 to 100 DIM, and 220 to 250 DIM. In addition, there would be the trimming required for normal occurring lame cows estimated to be 8 to 20 % of the herd per year.　With poor cow comfort, any type of organic bedding, slippery floors, or poor concrete floor surfaces, it is estimated that it would require 3.2 to 3.5 trims per cow per year.

In a farmstead design with rubber floors everywhere it is estimated that it would require 4 to 4.2 trims per cow per year. The hoof trims would be scheduled at the dry period, 40 to 60 DIM, and approximately every 90 to 100 days thereafter. In addition, there would be the trimming required for normal occurring lame cows estimated to be 10 to 25% of the herd per year.

To be efficient for the farm and the hoof trimmers it is ideal to have somewhere between 25 and 50 cows to trim at the same farm per day. This is because of travel, set up and clean up that is part of a farm visit. Some hoof trimmers will trim more cows per day.　However, there is a limitation for cows trimmed per day per person. The quality of trimming is diminished if the trimmer goes above a certain number of cows per day. This is a comprehensive job with many details. Professional consultants suggest that trimming 50 cows per day is good day for one person doing the hoof trimming. If conditions are good such as low lameness, practical trim setup, and cows that handle easy, this number for some of the good trimmers can go up to 75 cows per day before trimming fatigue sets in. That is about 6 to 10 cows per hour.

If timed hoof trimming is done in house it should be done so all the cows receive the required assessments per year as discussed above. Depending on the size of the herd this would be done daily, weekly, biweekly, or monthly.　Many of the in-house trimmers will trim between 40 and 60 cows per day on bigger farms if it is their full-time job.　On smaller farms they may trim 5 to 7 cows per week or whatever the work schedule allows.

Results

Hoof trimming schedules for a specific farm are dependent on the combination of housing, environment, and management factors described above. The scheduled hoof trimming is done on a daily, weekly, bi-weekly or monthly schedule depending on the size of the farm. Below shows how to determine a schedule for a farm. Some farms choose to have 2 to 4 hoof trimmer visits per year. They may trim the whole herd of cows at the same time or split the trimming of all cows up into the 2 - 4 visits. This system is not always optimal for cows but it is chosen (preferred) by the hoof trimmers for scheduling reasons. With smaller farms, good cow comfort, and ideal conditions that can work, although lame cows must be taken care of by the producer or someone else daily.　Some farms choose to trim every cow every 120 days. This can work with the right conditions and the right farm, but the timing is not always ideal for cows.　With this system, some cows will be trimmed during closeup or just fresh period which adds extra stress during this vulnerable time.

Step 1. Pick the trimming frequency for farm conditions.

Conditions	Trim frequency per cow per year
Optimal Cow Comfort	2.2 trims per cow per year
Organic bedding	3.2 trims per cow per year
Rubber Flooring	4.2 trims per cow per year

Step 2. Calculate the number of trimmings per year for the total herd size.
Total herd size (cows) X Trim frequency per cow per year = Number of trimmings per year

Step 3. Calculate the number of trim day visits per year based on hoof trimmer capacity of 50 trims per day.
Number of trimmings per year/ 50 trims per day = Number of trim day visits per year

Step 4. Determine trim day visit frequency according to table below.

Trim day visits per year	Trim day visit frequency	Cows trimmed per visit
< 10	Every other month	25-50
10 – 15	Every 5 weeks or monthly	25-50
16 - 25	Every 3 weeks	40-50
26 – 50	Bi weekly	40-50
51 – 100	Weekly	40-50
101 – 150	2 days per week	30-50
150 +	+3 days per week	30-50

Conclusions

Number of hoof trims per year is imperative for optimal claw function. Various management factors have a direct impact on determining number of trims per year. Implementing a schedule based on these factors has proven most beneficial for claw health and cow productivity.

Acknowledge

This study is an adaptation of the "Design and Management of Proper Cow Handling Systems" published by D. Kammel, K. Burgi and J. Lewis – Vet Clin Food Anim 2018.

A team approach to delivering a lameness control programme on farm

Reuben Newsome[1]*, Dave Phillips[1], Mark Burnell[1]**

Introduction

Early detection and appropriate treatment of lameness are important factors in lameness management (Groenevelt *et al.*, 2014; Thomas *et al.*, 2015, 2016), and lameness greatly predisposes further lameness (Randall *et al.*, 2015, 2018; Newsome *et al.*, 2016). Despite this knowledge, the practical application of "early detection and treatment" is challenging.

Lameness prevalence – both in the UK and globally – remains stubbornly high, with farmers identifying the key barriers to lameness control as (1) lack of time, (2) lack of skilled labour and training and (3) lack of appropriate trimming facilities (Manning *et al.*, 2016; Pedersen *et al.*, 2018).

Our aim was to deliver a commercial service that reduced lameness on farm through early detection and treatment of lame cows. Objectives included (1) perform all routine trims (two per cow per lactation) and all lameness detection and treatment, (2) attend newly lame cows within 48 hours, (3) charge for the programme based on the number of cows in the herd and (4) use technological aids to deliver an efficient service.

Materials and Methods

The farm

The farm milked 250 Holstein Friesian cows twice daily through an 18x36 swingover parlour, calving year-round. Cows were housed in cubicle sheds with rubber mattresses, straw bedding and concrete flooring. The collecting yard was rubber matted and low yielders had access to grazing for at least 100 days per year. Both an independent foot trimmer and one of our Vet Techs (foot trimmers) attended the farm approximately monthly until the beginning of this programme. Digital dermatitis was reasonably well controlled through footbathing twice weekly with formalin 2%. An on-farm foot trimming crush was used for lameness treatments.

Lameness detection

Three methods of lameness detection were used:

- Fortnightly mobility scores by a single ROMS (register of mobility scorers) scorer.
- CowAlert® (Ice Robotics, Edinburgh; system already installed on farm), which uses lying time algorithms to detect lameness. The team could view CowAlert® online.
- Farm staff could alert the team to any other lame cows.

The team

Two Vet Techs (DP performing all routine trims and some lame cows and RP mobility scoring) and two vets (RN and MB attending to lame cows) delivered the service. Farm staff separated out lame cows upon request and alerted the team if they noticed additional lame cows. Ice Robotics provided technical advice for the Cow Alert® system. Communication between all team members and farm staff was predominantly via a WhatsApp group.

Lameness treatment and recording

The target was to attend newly lame cows within 48 hours and treat according to the best available evidence (Thomas *et al.*, 2015). A triage system enabled Vet Techs to refer cows for further veterinary attention. An online spreadsheet (Google Sheets) was designed to capture all lameness treatments and automatically scheduled re-visits. It also allowed the team to access live records and to track cases closely over time.

Cost to farmer

The required work over a 12 month period was estimated and the project was charged slightly below the standard Vet Tech rate. This was calculated to be £50 per cow per year.

Cattle Lameness Academy, Synergy Farm Health Ltd, Dorset, United Kingdom, www.cattlelamenessacedemy.co.uk
*reuben.newsome@synergyfarmhealth.com
**dave.phillips@synergyfarmhealth.com

Results

The programme was delivered between January and October 2018. The most frequent causes of lameness were sole lesions (55% either sole ulcer or haemorrhage) and white line disease (19%), and digital dermatitis infection on claw horn lesions was a common reason for re-presentation.

At the initial mobility score in December 2017, 27% of the milking herd were lame (18% were mobility score 2 and 9% were score 3). By May, 10% of the herd were score 2 and none were score 3. Until this point, the on farm staff and CLA team worked well together and the service was efficient to deliver.

In May 2018, the farm manager decided to sell the herd and stop dairy farming. A series of events followed that prevented the sale of the herd until October 2018. During this time the herd manager left, the high-yielding and low-yielding groups were merged and temporary staff were brought in. Both the communication with farm staff and detection of lame cows by farm staff reduced greatly, and the service that we could deliver suffered. Lameness prevalence increased once again. Figure 1 presents mobility score data throughout the entire period, with key events annotated.

From the practice's financial perspective, the hourly rate charged was low, but the trimming on this farm and the overall project were new revenue streams for the practice. The work delivered compared to the cost billed worked out as approximately half-price for the farmer, had they paid in full for the services. The work-load was front-loaded and our input reduced throughout the period.

For the farm, they gained revenue from cull cows that would otherwise have been on-farm mortalities and cost the farmer. The herdsman reported that fertility had improved (until May) as they were displaying oestrus better, although there are inherent challenges with determining a cost/benefit regarding fertility and milk production. Additionally, the farm staff were relieved that lameness is being managed and the farm avoided penalties for lameness on the milk contract.

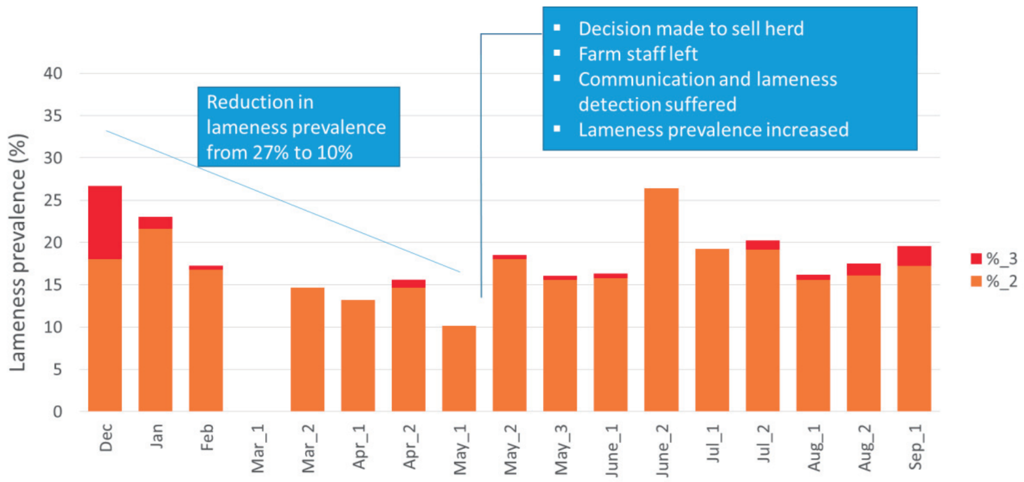


Figure 1: Fortnightly mobility scores throughout the period where a lameness control programme was delivered on a dairy farm. The AHDB Dairy mobility scoring method is applied, where "2" = lame and "3" = severely lame (Thomas *et al.*, 2015).

Conclusions

1. This approach can rapidly reduce lameness on farm. The service was tailored to the specific on-farm situation, meaning that in this case it had to focus primarily on the detection and treatment of lame cows. However, lameness control programmes must also emphasise reducing index lameness cases.
2. Team work was key, and the service was successful in reducing lameness when the communication between the on-farm team and the team delivering the service was good. The service was not successful when communication broke down.

Cattle Lameness Academy, Synergy Farm Health Ltd, Dorset, United Kingdom, www.cattlelamenessacedemy.co.uk
*reuben.newsome@synergyfarmhealth.com
**dave.phillips@synergyfarmhealth.com

3. This service was economically beneficial to the farmer, and the revenue gained from cull cows alone – that would otherwise have cost as on-farm mortalities – paid for the entire prevention service.
4. The service was a new revenue stream for the practice. It is an economically sound plan to have in the toolbox to offer to particular farms, but would need to be charged at a higher rate if rolled out to more farms due to the time and resource commitment it requires.

Acknowledgements

The authors would like to thank Rhiannon Purbrick for performing all the mobility scoring, as well as farm staff and the wider Cattle Lameness Academy team for support with this project.

References

Groenevelt, M., Main, D. C. J., Tisdall, D., Knowles, T. G. and Bell, N. J. (2014) 'Measuring the response to therapeutic foot trimming in dairy cows with fortnightly lameness scoring', *Vet. J.*, 201(3), pp. 283–288. doi: http://dx.doi.org/10.1016/j.tvjl.2014.05.017.
Manning, A., Mahendran, S. A. and Bell, N. J. (2016) 'Evidence base behind foot trimming in UK dairy cattle', 21(1).
Newsome, R. F., Green, M. J., Bell, N. J., Chagunda, M. G. G., Mason, C. S., Sturrock, C. J., Whay, H. R. and Huxley, J. N. (2016) 'Linking Bone Development on the caudal aspect of the Distal Phalanx with Lameness during Life', *J. Dairy Sci.*, 99(6), pp. 4512–4525. doi: 10.3168/jds.2015-10202.
Pedersen, S. L., Huxley, J. N. and Bell, N. J. (2018) 'Routine Cattle Foot Trimming: Current Practices and Future Research Areas', in *Cattle Lameness Acad. Semin. 2018*. Haselbury Mill, Somerset, UK, p. 17.
Randall, L. V., Green, M. J., Green, L. E., Chagunda, M. G. G., Mason, C., Archer, S. C. and Huxley, J. N. (2018) 'The contribution of previous lameness events and body condition score to the occurrence of lameness in dairy herds: A study of 2 herds', *J. Dairy Sci.* Elsevier, 101(2), pp. 1311–1324. doi: 10.3168/JDS.2017-13439.
Randall, L. V, Green, M. J., Chagunda, M. G. G., Mason, C., Archer, S. C., Green, L. E. and Huxley, J. N. (2015) 'Low body condition predisposes cattle to lameness: An 8-year study of one dairy herd', *J. Dairy Sci.*, 98(6), pp. 3766–3777. doi: http://dx.doi.org/10.3168/jds.2014-8863.
Thomas, H. J., Miguel-Pacheco, G. G., Bollard, N. J., Archer, S. C., Bell, N. J., Mason, C., Maxwell, O. J. R., Remnant, J. G., Sleeman, P., Whay, H. R. and Huxley, J. N. (2015) 'Evaluation of treatments for claw horn lesions in dairy cows in a randomized controlled trial', *J. Dairy Sci.*, 98(7), pp. 4477–4486. doi: http://dx.doi.org/10.3168/jds.2014-8982.
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', *Vet. Rec.*, 178, p. 116. doi: 10.1136/vr.103394.

Cattle Lameness Academy, Synergy Farm Health Ltd, Dorset, United Kingdom, www.cattlelamenessacedemy.co.uk
*reuben.newsome@synergyfarmhealth.com
**dave.phillips@synergyfarmhealth.com

The bovine claw is as well organized as an automobile independent suspension system

Hiroyuki Manabe
MH Corporation, Japan

Introduction

About a hundred years ago, the mass production manufacturing technique for automobiles made progress in leaps and bounds. An independent suspension of an axle was also developed at that time, and the driving performance and environment improved drastically. Upon considering the structure of the bovine claw, the movement of medial and lateral digits are completely functioning as an independent suspension. First, the alignment of the bovine P1, P2, and P3 is not straight like those of horses. They are zigzagged and articulated by ginglymus, consequently, they can work as suspensions individually. Second, each connection from pedal bone to the metatarsal and metacarpal bones, which play the axle of the automobile, firmly joins with a cruciate ligament. The pivot of the axle is the fetlock joint. So the quarter of the claw tend to wear more than the other parts. Specifically, medial claws become narrower and tilt axially in many cases.

Materials and Methods

Thinking that the claw is an independent suspension, the digital axis is set to each of the medial and lateral claws besides the center axis that is the ideal line running center of the metatarsal. The digital axis is perpendicular to the floor when the weight bearing surface is parallel to the corium. The inclination of the weight bearing surface is determined by the millefeuile hypothesis.
We investigated 10,625 hind left feet of Holstein cows which were trimmed in usual visits in 2018. We checked them in the air with a handle of hoof knife. Following 5 combinations of axes the degree they are parallel to the center axis or declined more than 5 degrees were recorded.
A: both axes are parallel to the center axis. B: the medial axis is declined axially and the lateral axis is parallel to the center axis. C: the lateral axis is declined axially and the medial axis is parallel to the center axis. D: both axes are declined axially. E: abnormal results

Results

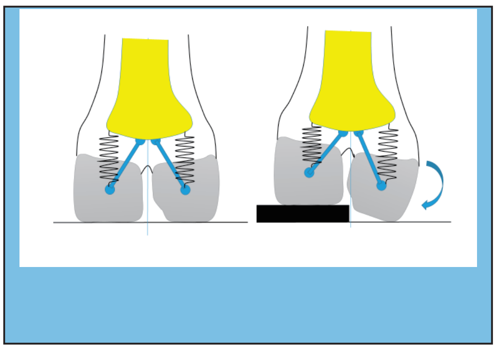
A 453(4.3%) B 9707(91.1%) C 223(2.1%) D 85(0.8%) E 157(1.5%)
This number includes 135 young heifers less than 26 months, and all of them were in the category B.

Conclusions

Usual hind claws are imbalanced, large lateral small medial. Small medial claws have to get enough height to balance large lateral claw. The corium parallel trimming method can be one of the methods used to maintain the balance of the claws.

Acknowledge (if needed) References (if needed)

Toussaint Raven E: Cattle Foot Care and Claw Trimming
Greenough PR, Weaver AD: Lameness in Cattle
Roger Blowey: CATTLE LAENESS and HOOFCAE
K. Nuss N. Paulus: Measurements of claw dimensions in cows before and after functional trimming: A post-mortem study, The Veterinary Journal 172 (2006) 284-292



Evaluating the effect of a mid-lactation hoof trimming on lesion prevalence in dairy cows

Gerard Cramer[1], Nigel Cook[2], Sarah Wagner[3], Grant Stoddard[4]

Introduction

Lameness caused by hoof lesions is an economic and welfare concern in the dairy industry. Hoof trimming is a commonly recommended preventative intervention yet studies indicating appropriate timing and technique for the procedure are limited. The objective of this project was to determine if cows receiving a mid-lactation hoof trimming had reduced lesion incidence at their next scheduled hoof trimming compared to that did not receive a mid-lactation hoof trimming.

Materials and Methods

This randomized trial occurred on a farm using free-stall housing, recycled sand bedding and a regular HT schedule. This farm was part of a larger study that evaluated the impact of 2 modelling techniques on lesion occurrence at their mid lactation hoof trimming. When cows were evaluated at their mid lactation (90-165 days in milk) hoof trimming for the original study they were enrolled in the current study. Only cows with no hoof lesions or not in need of a hoof trimming due to having overgrown hooves were eligible for inclusion into the current study. Cows were allocated to receive 1 of 3 treatments at their mid-lactation hoof trimming at the time of the original study enrolment. Treatment groups consisted of, 1) odd numbered cows were just restrained and evaluated for lesion (NOTRIM), 2) even numbered cows that were allocated to the same larger modelling technique as in the original study (BIG), 3) even numbered cows that were allocated to the same smaller modelling technique as in the original study (LIT). The presence or absence of lesions was determined at the cow's next scheduled hoof trimming around the time of drying off. Our main outcome of interest. Using Bayesian analysis with non-informative priors, the odds of having a lesion present at the cow's next hoof trimming was determined for each of our treatment groups.

Results

A total of 778 cows were enrolled into the study with 376 in NOTRIM, 190 in LIT and 212 in BIG. Average DIM at enrolment 113 and 556 (71%) of the cows were Holstein with remainder being crossbreds. A total of 208 (27%) did not receive a subsequent hoof trimming. Average DIM of the 570 cows that received a next hoof trimming was 289. At the next hoof trimming 108 (19%) if cows had a lesion. White line disease was the most frequent lesion at next hoof trimming with 12% of cows affected. The odds of a cow having a lesion was 1.4 (95% Credible Interval 0.8-2.2) for cows trimmed in the BIG group, and 1.3 (95% Credible Interval 0.7-2.0) for cows in the LIT group compared to cows that did not receive a trim.

Conclusions

Results from our study showed a lack of evidence of mid-lactation hoof trimming reducing hoof lesion prevalence. Our credible intervals showed a wide range of plausible effects ranging from 20-30% lower odds of lesions to a 2.2 higher odds of lesions. Since this study was completed in only 1 herd with 1 hoof trimmer in a high hoof wear environment results from this study might not be generalizable to other types of housing systems. In addition, in our project all cows were evaluated in the hoof trimming chute at 100 DIM and only cows without lesions were enrolled in the study. Herds in high wear environments should only consider not doing mid lactation hoof trimming if they have excellent lameness detection strategies.

[1] Department of Veterinary Population Medicine, University of Minnesota, St. Paul, MN 55108
[2] Food Animal Production Medicine Department, University of Wisconsin Madison
[3] Department of Animals Science, North Dakota State University
[4] Cargill Animal Nutrition, Eagan, MN
* E-mail: gcramer@umn.edu

Acknowledgements

The authors want to acknowledge the generous support from the American Association or Bovine Practitioners, Hoof Trimmers Association, the University of Minnesota Population Systems Signature Program and the Dr. RK Anderson and Ruth E. Foster and MN Drive fellowships for their financial support of Dr. Stoddard

Prevention of claw disorders by strategic maintenance trimming in relation to calving time.

Christer Bergsten[1,2,*], Frida Åkerström[2], Ann Nyman[2]

Introduction

Traditionally in Sweden, the whole herd was trimmed at the same time and preferably at the end of housing season in connection with grazing. In most herds today trimming is extended to two times yearly, with autumn and spring trimming as the most common trimming periods. An earlier Swedish experimental study showed that trimming twice yearly with an average interval of 135 days reduced lameness and traumatic claw horn disorders (sole ulcer, white line disease, double sole) compared with trimming only once [1]. In larger and more high producing herds trimming routines have been changed and is performed more evenly throughout the year. Trimming or claw care of each cow twice yearly is the today´s recommendation and to obtain this, more than two yearly herd visits are often needed. In a more recent study among herds trimming twice yearly it was shown that the risk for sole ulcer decreased significantly with a shorter trimming interval than 175 days [2]. Most trimmings in Sweden are made by professional trimmers self-learned or with some kind of foot trimming schooling. Today, claw disorders are recorded voluntarily and reported nationally for 75 % of the Swedish dairy cows. Several visits to the herd by the foot trimmer opens possibilities to direct the trimming to when it is most needed for the individual cow in order to detect, treat and most important, to prevent claw disorders to occur.
The aim of present study was to investigate if a strategic maintenance trimming, in relation to calving time, could improve claw health and survival of dairy cows.

Materials and Methods

The definition of a strategic foot care, i.e. a standard operating procedure (SOP), in the present study was that claw check with functional trim was made at dry off, i.e. about two months (90-30 days) before expected calving, and then again about two months (30-90 days) after calving. This gives a trimming interval of about four months during the period around calving when cows are most susceptible to claw disorders. If an injury causing lameness is detected or if the trimming program operates with three trimmings per lactation, the cow should preferable be examined again four months after previous trimming (Figure 1).

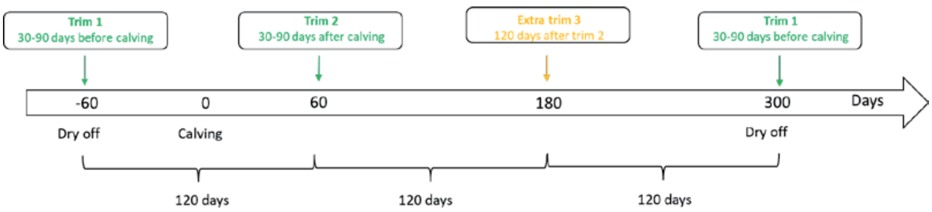


Figure 1: Schedule of strategic maintenance foot trimming in relation to calving time.

To analyse if there was an association between applying the strategic foot care program and the prevalence of claw disorders and culling, data was collected from the National Milk Recording Scheme (NMRS) including claw health records, from 202 larger dairy herds from January 2014 until March 2018. First parity cows were identified in the dataset, as well as time from first and second calving to all recorded trimmings. The claw health records followed the Nordic Claw Atlas recommendations where the most common remarks were graded as mild or severe. Moreover, before analysis the diagnoses were categorised as: healthy, mild infectious or traumatic, severe infectious or traumatic, and chronic traumatic claw disorder, respectively (Table 1).

1 Swedish University of Agricultural Science, Sweden
2 Department of animal health and development, Vaxa Sverige, Sweden

Table 1: Categorisation of recorded claw disorders in the analysis.

Diagnose	Symptom
Healthy	Cows without any remark at any claw at the actual trimming
Severe infectious	Digital dermatitis (DD, M2), Foot rot, Interdigital hyperplasia, Wart growth (chronic proliferative dermatitis, M4)
Mild infectious	Dermatitis (Interdigital dermatitis), Heel horn erosion
Severe traumatic	Sole ulcer, Toe ulcer, White line ulcer or abscess
Chronic traumatic	White line lesion, Double sole, Laminitic wall ridge
Mild traumatic	Sole haemorrhage

Descriptive statistics was used to describe the prevalence of cows with claw health remarks for cows trimmed according to SOP and cows not trimmed according to SOP, as well as proportion of cows culled i.e. slaughtered or euthanized as carcass due to claw and leg disorders or other reason. Univariable mixed logistic regression analysis was used to assess if there was an association between being trimmed according to SOP or not and presence of claw disorders at the trimming after calving. Moreover, associations between being trimmed according to SOP or not and slaughtered or being euthanized due to foot and leg disorders was also investigated using univariable mixed logistic regression analysis. In the regression analysis herd was included as random factor to adjust for cows being more similar within herd than between herds.

Results

In total, 44,584 first parity cows were included in the statistical assessments, and 2,289 (5%) of these were trimmed at second calving according to our definition of SOP. The proportion of disorders is presented in Table 2.

Table 2: Claw disorders recorded at first trimming after second calving for cows trimmed according to standard operating procedure (SOP) or not trimmed according to SOP.

Remarks	Trimmed according to SOP	Not trimmed according to SOP	Total
Healthy	1,519 (66%)	26,766 (63%)	28,285 (63%)
Severe infectious	191 (8%)	4,572 (11%)	4,763 (11%)
Mild infectious	309 (13%)	5,642 (13%)	5,951 (13%)
Severe traumatic	39 (2%)	1,236 (3%)	1,275 (3%)
Chronic traumatic	81 (3%)	1,170 (3%)	1,251 (3%)
Mild traumatic	115 (5%)	2233 (5%)	2,348 (5%)
Hock lesion	1 (0,04%)	45 (0,1%)	46 (0,1%)
Claw shape	34 (1%)	631 (1%)	665 (1%)
Total	2,289 (5%)	42,295 (95%)	44,584 (100%)

According to the results of the univariable regression model there was a significant lower risk for cows trimmed according to SOP to have severe infectious (OR=0.83, p=0.04) or traumatic (OR=0.71, p=0.05) claw disorders at first trimming after calving than cows not trimmed according to SOP. Moreover, cows trimmed according to SOP had significantly less remarks of abnormal claw conformation (OR=0.65, p=0.02).

In total 12,121 cows in second lactation were culled and the proportion of cows slaughtered or euthanized is presented in Figure 2.

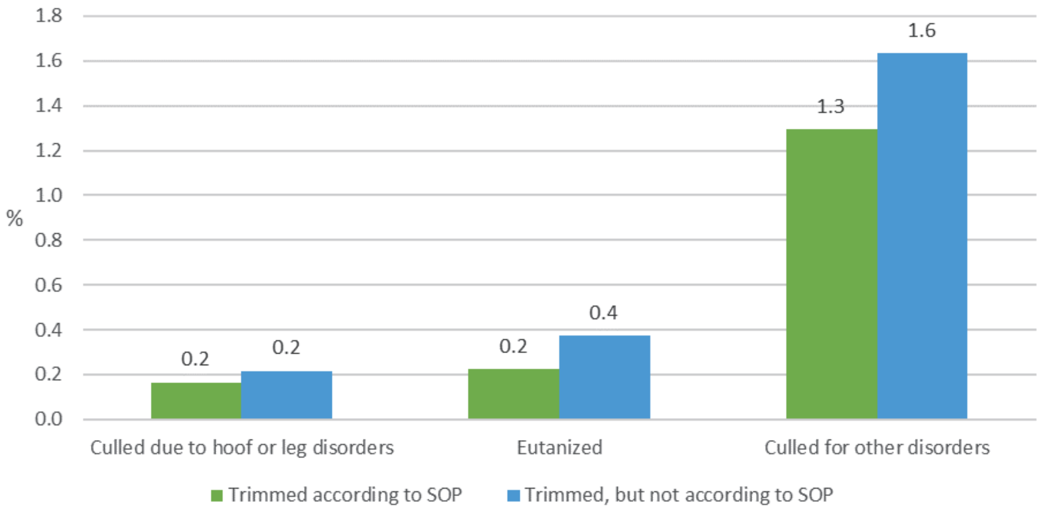


Figure 2: Proportion of cows slaughtered or euthanized due to foot or leg disorders, or due to other disorders for cows with claw trimming performed according to SOP or not (n=36,009 cows in 202 dairy herds in Sweden, 2014-2018).

The regression analysis showed a significantly lower risk for being slaughtered (OR=0.59, p=0.003) or to be euthanized (OR=0.53, p<0.001) due to a foot or leg disorder for cows trimmed according to SOP.

Conclusions

A strategic maintenance trimming in the period around calving can result in less severe infectious and severe traumatic claw disorders, less abnormal claw conformation and a lower risk for culling or being euthanized in the following lactation compared with not trimmed according to SOP.

Acknowledgements

This project was financed by the Swedish Board of Agriculture.

References

1. Manske, T.; Hultgren, J.; Bergsten, C. The effect of claw trimming on the hoof health of Swedish dairy cattle. *Preventive veterinary medicine* **2002**, *54*, 113-129.
2. Bergsten, C.; Carlsson, J.; Jansson Mork, M. Influence of grazing management on claw disorders in swedish freestall dairies with mandatory grazing. *Journal of dairy science* **2015**, *98*, 6151-6162.

Design and Management of Proper Handling Systems for Dairy Cows: A Hoof Trimming Application

David W. Kammel[1], Karl Burgi[2], Jim Lewis[3] and Kimberly Evert[4]

1. Professor, Biological Systems Engineering University of Wisconsin,　Madison, WI USA
2. Owner, Sure Step Consulting International, LLC,　Baraboo, WI USA
3. Owner, Stepright Stockmanship Solutions, LLC,　Colfax, WI USA
4. Hoof Health Research Director, Sure Step Consulting International, LLC　Baraboo, WI USA

Introduction

A whole systems design approach to the cow handling system optimizes cow welfare and production.[1] Proper handling system design and management is inclusive of the concepts of being safe, efficient, and effective and the result is a successful system that benefits the cows, stock persons, and the dairy business. The cow handling system is a tool to allow the implementation of a management plan.[2]

Design and management are both essential for a successful cow handling system design. The three key components are:

1. The skills of the stock person (Stockmanship)
2. The cow handling management plan
3. The design of the facility

Excellent stockmanship skills can compensate for a poor cow handling facility design, but a properly designed cow handling system design enhances the opportunity to leverage excellent stockmanship skills and a cow handling management plan.　The three afore mentioned components were further assessed for in-field hoof trimming application.

Materials and Methods

The redirection box is a design that eventually was named after Bud Williams who learned how to use the design as an alternative to a crowding tub. (Figure 1) It takes both good design and good handling skills to use the system properly. The basic dimensions of the redirection box are 12-14' wide by 20' long. Cows waiting in a holding area are worked through the bud box in small groups. The group size will be dependent on the capacity of the race leading out of the bud box and to the hoof trimming chute. If the race can hold 5 cows, then the group size worked into and out of the bud box should be 5 cows. Permanent bud boxes can be integrated into a permanent handling system design for hoof trimming areas.

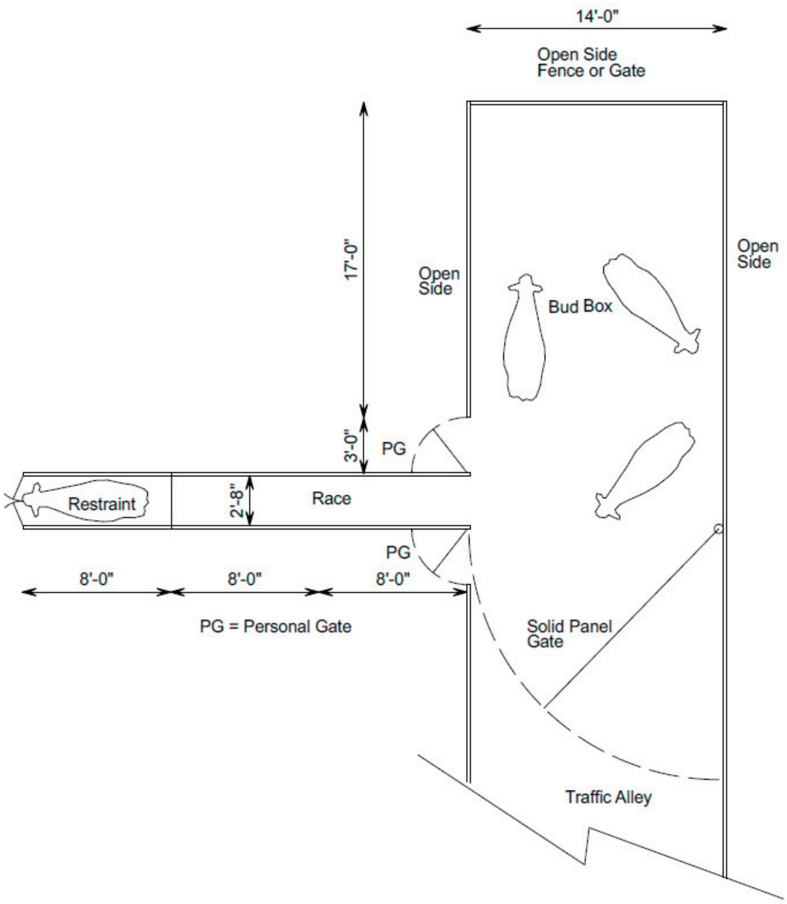


Figure 1.

The capacity for holding cows and trimming the cows in a reasonable time frame should be determined in the facility design. The holding pen should be sized to hold the number of cows that can be trimmed in less than a 2 hour period. Professional hoof trimmers can provide a quality trim to each cow and still trim between 40 - 50 cows per 8 hour day or 5-6 cows per hour. That would make the holding area sized for approximately 10-12 cows. Designing an efficient handling system will pay off in lowering the time required to move cows out of the pen into the holding area and return to their pen.

Hoof trimming areas for smaller dairies for a scheduled trimming can be temporary setups with a portable chute brought by the trimmer. Figure 2. Temporary bud boxes can be set up outside and on the end of the freestall barn for periodic use by the hoof trimmer or for loading and unloading cattle. The bud box is placed at the end of the alley of a freestall pen using one alley as an extension into a Bud box and set up of hoof trim chute or load out area perpendicular to the direction of the alley and bud box. When cows are released from the trim chute they can exit into the other alley.

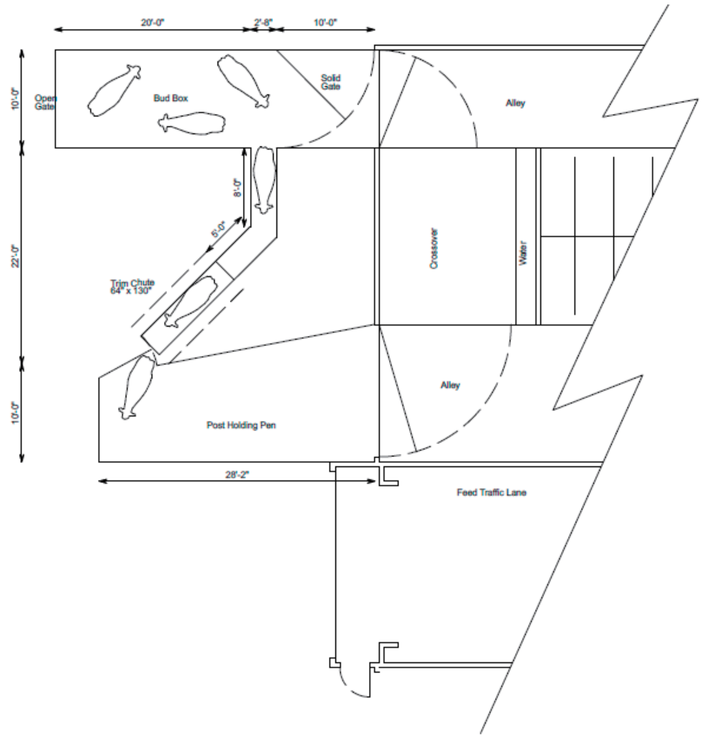


Figure 2.

Figure 3. shows a dedicated cow handling space that allows for the dual purposes of a permanent trimming chute and head gate. The holding area uses a swinging gate to funnel cows into the race. The race can be split to feed either a dedicated trimming chute or a head gate.

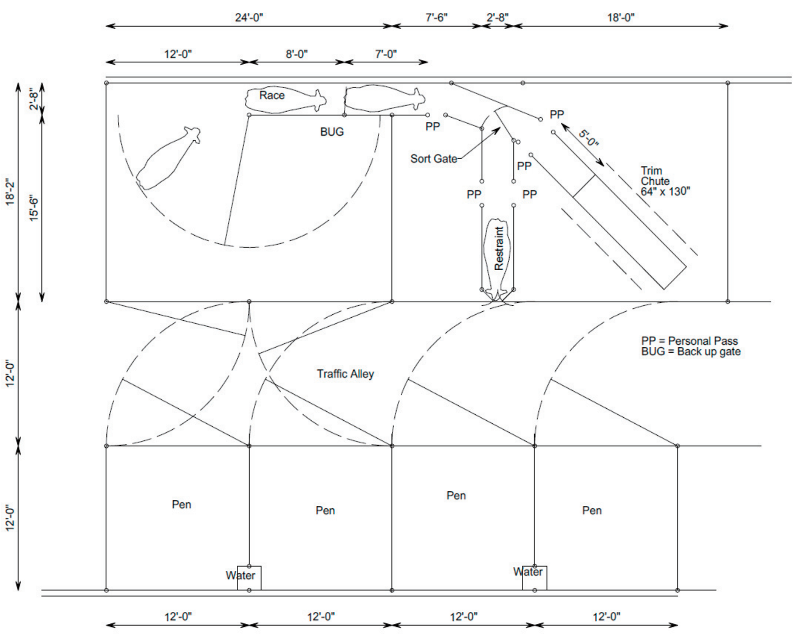


Figure 3.

Figure 4 shows a compact design for a larger dairy that uses a dedicated bud box to feed a simple race and a dedicated trimming chute for as needed trimming. (Photo 1)

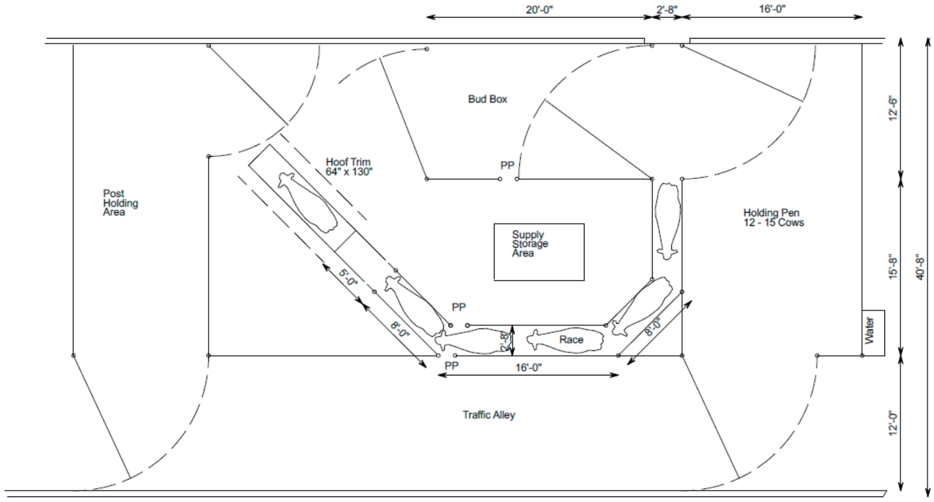


Figure 4.

Photo 1.

This design can be adapted to provide both an as needed trimming chute and allow a professional trimming chute. (Photo 2) (Figure 5) The professional trimmer brings their own chute and can back it into the dedicated handling space. Note the gate on the bud box entrance is hinged at the exit to create a longer race to hold an additional two cows.

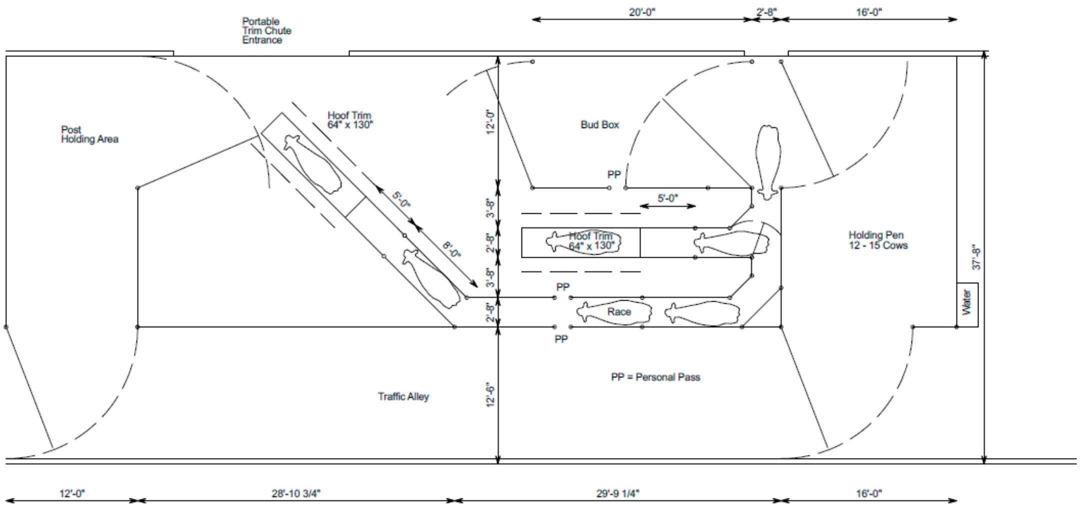


Figure 5.

Photo 2.

Figure 6 shows a design with space for a permanent holding area, bud box integrated into the traffic alley, curved race and a dedicated hoof trimming space.

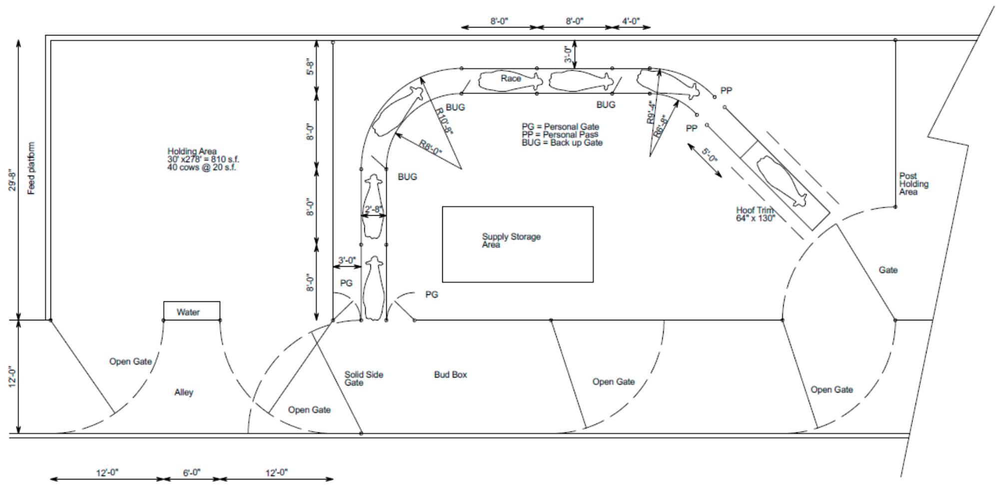


Figure 6.

Figure 7 shows a dual purpose handling area for either restraint in a head gate for cows or a dedicated hoof trimming chute for the in house hoof trimmer.

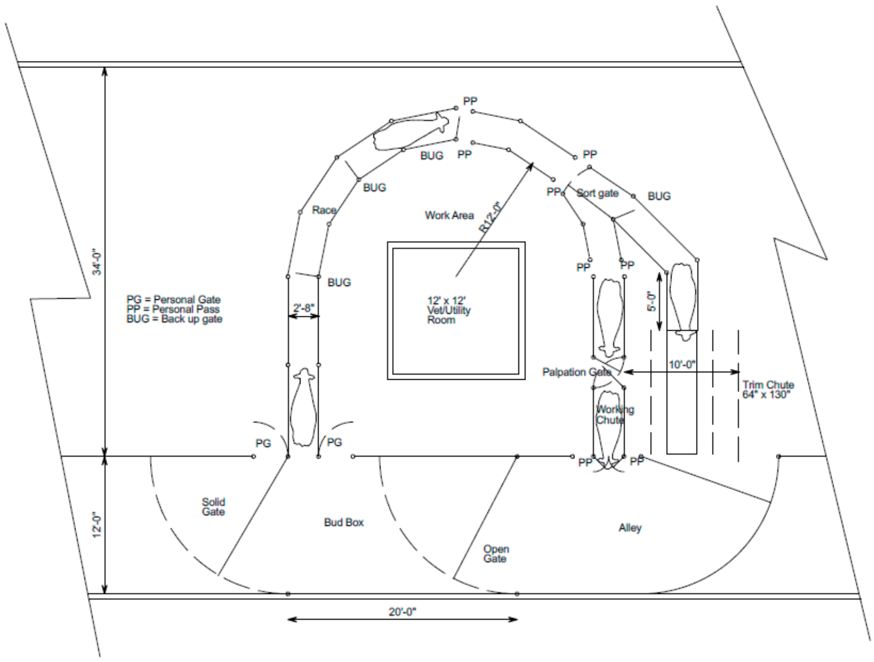


Figure 7.

Figure 8 shows a design that integrates a bud box into the traffic alley. Three options for cow handling are integrated into the curved race design. There is a palpation management rail that also acts as a race to feed a curved race. The race can either feed a dedicated trimming chute or a head gate for cow restraint.

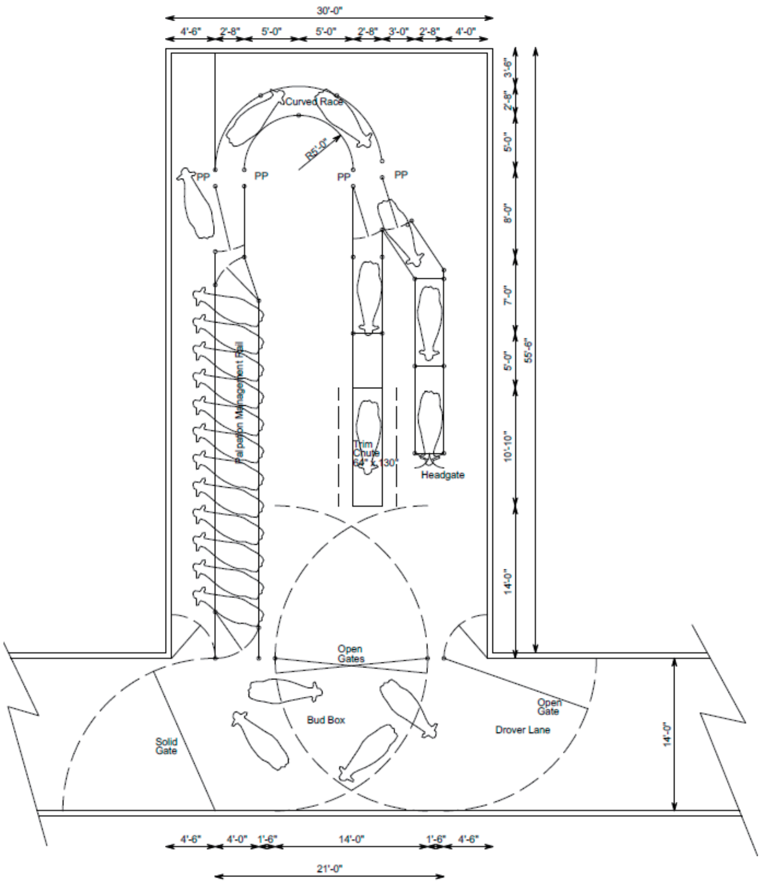


Figure 8.

Results

The afore mentioned bud box dimensions proved optimal in on-farm permanent and temporary hoof trimming set ups at various facilities.　Cows demonstrated calmer demeanors while entering the race from the bud box, while being held in the race, and while entering and exiting the chute.　It was frequently demonstrated that cows would self-load into the race from the Bud Box: minimizing technician steps and increasing work productivity.

Conclusions

The design and management of proper handling systems for dairy cows begins with a cow handling management plan that considers the cow and the stockman behavior. The safety of the cow and stockman are important to the cow handling management plan and design decisions. Cow welfare and wellbeing can be addressed in proper cow handling system design. The three key components of a handling system are the skills of the stockman, the cow handling management plan, and the design of the handling facility. Good design enhances stockmanship ability and minimizes stress for cows and stockman lowering the risk of injury to both.

Acknowledge

This study is an adaptation of the "Design and Management of Proper Cow Handling Systems" published by D. Kammel, K. Burgi and J. Lewis – Vet Clin Food Anim 2018.

References

1. Grandin, T. A whole systems approach to assessing animal welfare during handling and restraint. In: Livestock Handling and Transport. 4th Edition. 2014. p 1-13. https://www.cabi.org/vetmedresource/ebook/20143217251
2. Jones, G. A., Kammel, D. Large dairy herd design and systems in temperate and cold climates. In: Large Dairy Herd Management. 3rd Edition. 2017. p 71-82. https://ldhm.adsa.org/

Survival of digital dermatitis treponemes in faecal and bedding microcosms

Jennifer Bell[1], Nicholas J. Evans[1], Roger Blowey[2]*

Introduction

Digital dermatitis (DD) is an infectious ulcerative dermatitis typically affecting the skin of the hind feet of dairy cattle worldwide with substantial welfare and economic implications making this disease an important issue for the dairy industry. A polytreponemal aetiology has been described with three distinct cultivable treponeme phylogroups (*Treponema medium, Treponema phagedenis* and *Treponema pedis*) consistently detected within DD lesions. Current control strategies fail to eliminate DD on farm and little is known about transmission (Sullivan et al 2014). Identifying the infection reservoirs of DD treponemes, and the period of survival in different bedding microcosms could develop new prevention strategies.

Materials and Methods

Faecal and bedding microcosm experiments were carried out in triplicate on separate days. Within each experiment there were three replicates of each microcosm. Faecal microcosms were spiked with DD treponemes either T. medium phylogroup strain T19, T. phagedenis phylogroup strain T320A or T. pedis phylogroup strain T3552B in triplicate. Faecal microcosms were aerobically incubated at 12 °C for 7 days. On each of the 7 days the microcosms were inoculated into culture medium enriched for treponemes and growth and motility scored by phase contrasts microscopy. Microcosms inoculated into media were then growth and motility scored by phase contrast microscopy after 7 days and 28 days anaerobic incubation at 36 °C.

Results

The DD treponemes remained viable in faecal microcosms which were incubated aerobically for a median of 1 day and with a range of 0-6 days.

In five different bedding microcosms under aerobic conditions, DD treponemes were viable for the full 7 days of the study in sand bedding, for 6 days in sawdust and for 5 days in recycled manure solids (RMS). However, DD treponemes were not viable at any time point when inoculated into bedding microcosms of straw or sand containing 5% (w/w) lime.

1. Department of Infection Biology, School of Veterinary Science, University of Liverpool, UK
2. Wood veterinary Group, Gloucester, UK
   - rogerblowey@mailbox.co.uk

Conclusions

Previous studies had shown that we were readily able to detect DD treponemes on the foot trimming blades, with 79% cattle blades positive for DD treponemes and all blades from cattle with DD lesions positive for DD treponemes [14]. The current results show that DD treponemes appear to survive and remain viable in faeces for up to six days and in bedding of sand, sawdust and recycled manure solids for 5 – 7 days. This must represent a potentially important mode of transmission. However viability was zero in straw and sand mixed with lime, the latter having a high pH. Field studies have previously associated straw bedding with a low incidence of DD.

Survival of DD treponemes for up to six days in faeces enables a substantial window of opportunity for subsequent transfer to another animals foot, and hence ncreasing hygiene on farm should help to reduce DD.

Acknowledge

Thanks are due to Richard Murray and Stuart Carter who supervised this project, and to the many farmers who allowed us to take samples.

References

Sullivan LE, Blowey RW, Carter SD, Duncan JS, Grove-White DH, Page P, Iveson T, Angell JW, Evans NJ. Presence of digital dermatitis treponemes on cattle and sheep hoof trimming equipment. Vet Rec. 2014, 175: 201.

Survival of Treponemes on Hoof Knives and Disinfection to Prevent Transmission

Amy Gillespie[1]*, Roger Blowey[2], Stuart Carter[1] and Nicholas Evans[1]

Introduction

Digital dermatitis (DD) is an infectious foot disease of cattle, affecting a large proportion of dairy herds worldwide. The pain and lameness caused by this condition is a source of economic loss to the dairy industry and is a major welfare concern.

Although many species of bacteria have been found within lesions, treponemes are the most commonly associated micro-organisms[1]. In the UK three distinct groups of treponemes have been isolated from DD lesions [1, 2].

Previous work has identified that hoof knives used to routinely trim cows' feet are likely to carry infection and are potentially a significant means of disease transmission. When used to trim hooves of cows infected with DD, all knives became contaminated with treponemes, and an isolate belonging to the *Treponema phagedenis*- like spirochaetes was cultured, despite inherent difficulties in growing these organisms under laboratory conditions[3]. The risk of disease transmission during foot trimming depends on the survival times of viable treponemes on hoof knives, and the infective dose required.

Disinfection of hoof knives between animals is not routinely carried out by farmers, veterinary surgeons or foot trimmers and there is currently no proven and practical disinfection regime. With the increasing use of dedicated foot trimmers working on multiple dairy farms, there is growing concern that this might be a possible route of transmission to uninfected herds. Twenty years ago, the use of a primary hoof trimmer who trims cows' hooves at other farms, and lack of washing of hoof trimming equipment between cows being trimmed, were found to be associated with increased incidence (>5%) of digital dermatitis in herds[4]. A 2018 study of pasture-based herds in New Zealand supported these findings, and the authors concluded that farms with DD should ensure that hoof trimming equipment is disinfected effectively between cattle[5]; a view that was also supported following an epidemiological study of risk factors for increased prevalence of digital dermatitis in 39 Danish dairy herds[6]. Disinfection of hoof trimming equipment should form part of a holistic approach to DD control.

The work presented here is in two parts. The first part is a survival study which assesses the risk of transmission of DD on hoof knives by testing survival times of treponemes on hoof knife blades. The second part is a disinfection study which tests a range of common disinfectants for removing viable treponemes from hoof knife blades, thereby reducing the risk of transmission of DD between cows during foot trimming.

[1] Infection Biology, Institute of Infection and Global Health, University of Liverpool; 2. Wood Veterinary Group, Gloucester
* E-mail: amyg@liverpool.ac.uk

Materials and Methods

A survival study was undertaken to establish how long two strains of treponeme (T320A belonging to the *Treponema phagedenis*-like group, and T3552B belonging to the *Treponema pedis* group) can survive on hoof knife blades. Strains of these organisms were cultured in liquid medium and diluted to standardized optical densities as previously described[10]. Bacteria were applied to hoof knife blades and swabs taken after two minutes and inoculated into liquid medium to serve as positive controls. After a series of specified waiting times, swabs were taken again, the first for inoculation into liquid medium and the second for direct detection of treponemes using a previously developed nested PCR assay[5]. Waiting times were 10 minutes, 1 hour, 2 hours, 4 hours and 18 hours.
As in the survival time study, the disinfection study used two strains of treponemes (T320A and T3552B) inoculated onto hoof knife blades and positive control swabs were taken after two minutes. Blades were disinfected for 20 seconds using one of the following: water, 2% Virkon® (Dupont) and 2% sodium hypochlorite, 2% glutaraldehyde, 5% copper sulphate, or 1:100 FAM30® (Evans Vanodine). As in the survival time study, two swabs were taken post-disinfection: one for bacterial culture and one for nested PCR.

Results

It was consistently possible to culture both strains of treponeme from hoof knives for up to two hours after inoculation. All samples remained positive by PCR testing for the full 18 hours waiting time (Table 1).
Three disinfectants completely prevented treponeme growth under laboratory conditions: 1:100 FAM30®, 2% Virkon® and 2% sodium hypochlorite. Of these, 2% Virkon® and 2% sodium hypochlorite yielded the best results in terms of destroying bacterial DNA in 18/26 (69.2%) and 20/31 (64.5%) of cases respectively (Table 2).

Conclusions

The finding that viable treponemes can be grown from hoof knife blades for up to two hours confirms that contamination of knives during foot trimming could be a potential risk for transmission of DD, both between cows in the same herd, and between herds. It is therefore important for the industry to develop a feasible and effective disinfection protocol for use during foot trimming. The laboratory results presented here suggest that the use of 2% Virkon® or 2% sodium hypochlorite with 20 seconds contact time may be suitable for this purpose, although risk may be further reduced by improving the rate of destruction of bacterial DNA. This could be achieved by using longer contact times.
The disinfection of foot trimming equipment together with increased hoof hygiene through slurry management and regular foot bathing should help mitigate most known potential transmission routes of BDD and underpin effective control.

Acknowledge

This project was funded by BBSRC and AHDB Dairy.

References

1. Evans NJ, Brown JM, Demirkan I, Singh P, Getty B, Timofte D, et al. Association of Unique, Isolated Treponemes with Bovine Digital Dermatitis Lesions. Journal of Clinical Microbiology. 2009;47(3):689-96. doi: 10.1128/jcm.01914-08. PubMed PMID: WOS:000263818800025.
2. Evans NJ, Brown JM, Demirkan I, Murray RD, Vink WD, Blowey RW, et al. Three unique groups of spirochetes isolated from digital dermatitis lesions in UK cattle. Veterinary Microbiology. 2008;130(1-2):141-50. doi: 10.1016/j.vetmic.2007.12.019. PubMed PMID: WOS:000257646600015.
3. Sullivan LE, Blowey RW, Carter SD, Duncan JS, Grove-White DH, Page P, et al. Presence of digital dermatitis treponemes on cattle and sheep hoof trimming equipment. Veterinary Record. 2014;175(8):201-+. doi: 10.1136/vr.102269. PubMed PMID: WOS:000344066800022
4. Wells SJ, Garber LP, Wagner BA. Papillomatous digital dermatitis and associated risk factors in US dairy herds. Preventive Veterinary Medicine. 1999;38(1):11-24. doi: 10.1016/s0167-5877(98)00132-9. PubMed PMID: WOS:000078458600002.
5. Yang DA, Laven RA, Heuer C, Vink WD, Chesterton RN. Farm level risk factors for bovine digital dermatitis in Taranaki, New Zealand: An analysis using a Bayesian hurdle model. Veterinary Journal. 2018;234:91-5. doi: 10.1016/j.tvjl.2018.02.012. PubMed PMID: WOS:000432233900016.
6. Oliveira VHS, Sorensen JT, Thomsen PT. Associations between biosecurity practices and bovine digital dermatitis in Danish dairy herds. Journal of Dairy Science. 2017;100(10):8398-408. doi: 10.3168/jds.2017-12815. PubMed PMID: WOS:000410876600060.

Table 1 …: Results from the survival study showing treponemes can be cultured from hoof knife blades for 2 hours, and detected by PCR for at least 18 hours after inoculation

Treponeme strain (phylogroup)	T320A (Group 2)		T3552B (Group 3)	
Survival Time	Positive cultures	Positive PCRs	Positive cultures	Positive PCRs
10 minutes	3/3	3/3	3/3	3/3
1 hour	3/3	3/3	3/3	3/3
2 hours	2/3	3/3	3/3	3/3
4 hours	0/3	3/3	0/3	3/3
18 hours	0/3	3/3	0/3	3/3

Table 2 …: Results from the disinfection study showing varied efficacy of disinfectants (20 seconds exposure) against treponemes on hoof knife blades

Treponeme strain (phylogroup)	T320A (Group 2)		T3552B (Group 3)	
Disinfectant	Positive cultures	Positive PCRs	Positive cultures	Positive PCRs
Water	6/12	10/12	13/16	16/16
2% Virkon	0/13	6/13	0/13	2/13
2% Sodium Hypochlorite	0/15	10/15	0/16	1/16
2% Glutaraldehyde	2/15	15/15	0/11	11/11
5% Copper Sulphate	1/16	13/16	2/17	11/17
1:100 FAM30	0/11	11/11	0/12	12/12