RISK FACTORS ASSOCIATED WITH FOOT LAMENESS IN DAIRY CATTLE AND A SUGGESTED APPROACH FOR LAMENESS REDUCTION

Christoph K.W. Mülling[1], Laura Green[2], Zoe Barker[2], Jeremy Scaife[3], Jonathan Amory[3], Marijntje Speijers[4]

[1]Institute of Veterinary Anatomy, Freie Universität Berlin, Germany
muelling@zedat.fu-berlin.de
[2]Ecology and Epidemiology Group, Dept of Biological Sciences, University of Warwick, UK
[3]Centre for Equine and Animal Science, Dept of Science Agriculture and Technology, UK
[4]Agri-Food and Biosciences Institute (AFBI), Northern Ireland, UK

1. INTRODUCTION

Lameness in cattle is a clinical sign with a multifactorial aetiology. A focused programme for lameness reduction requires that farmers and their advisors recognise the main types of lameness occurring in cattle on their farm(s) and know the seasonal and lactational patterns of lameness and the management and environment of these cattle. In this paper we propose an approach to targeting cattle lameness using the above information together with published and new findings on risks for lameness in cattle to move towards targeted programmes for reduction in lameness. Whilst we still have many questions on the aetiology and pathogenesis of the lesions associated with lameness, research from the last 10 years can assist our understanding and we anticipate that research in the next 10 years will strengthen this understanding so that we can be more accurate in targeted programmes that reduce lameness in dairy cows.

2. CATTLE AT RISK

A programme of lameness reduction necessitates that when cattle feet are trimmed, either when routine hoof trimming or when trimming lame cows' feet, that any lesion observed is recorded along with the cow identity, foot affected, date of trimming and whether the cow was lame or not and to what degree. Using these data the patterns of type and localisation of lesion, season of the year, stage of lactation and the lesions causing lameness can be summarised. Combining these patterns with the environment and management on the farm and with the information on risk factors associated with lameness from research studies, and then taking action to reduce these risks is the start of a lameness reduction programme. One key area where we have little information to date is the time taken for lesions to develop. For example, we may know that a particular herd has a high prevalence of sole ulcers which are treated when cows are 3-5 months in their lactation cycle. Ideally from this we would like to know:

- what is a target level to reduce the prevalence of sole ulcers to and,
- when did the risk for sole ulcer development occur?

For sole ulcers we already know that the disruption of horn production by damage to living horn producing cells occurred about 6-8 weeks ago. For acute events such as acute laminitis initial changes precede the clinical symptoms by 24-48 h. For other lesions associated with lameness these questions remain mostly unanswered. Most of the lesions we record are chronic in terms of their development and duration. Thus we can speculate that some lesions take months to develop and others weeks. Despite this lack of knowledge, careful recording of lameness events now will ensure that farmers can implement changes as soon as research provides some of the answers to these questions.

3. RISKS ASSOCIATED WITH FOOT LAMENESS IN DAIRY CATTLE

Factors influencing whether a cow becomes lame can be considered in two groups.

3.1 Intrinsic, unavoidable risks

There are intrinsic risks for lameness that cannot be changed. These include season (MacCallum *et al.* 2002), gestation and stage of lactation (Knight, 2001; Green *et al.* 2002), previous disease (Alban *et al.* 1996; Hirst *et al.* 2002) and parity (Hirst *et al.* 2002; Hedges *et al.* 2001; Potzsch *et al.* 2003). There is also a genetic determined intrinsic risk for development of lesions (Boettcher *et al.* 1998; Koenig *et al.* 2005). The age of cattle cannot be altered but age can be managed carefully, either through appreciation that older cows may be more likely to become lame, and so allocating time for prompt treatment, or through a culling programme for cows that are repeatedly lame. It is, however, possible to moderate the extrinsic risks from the environment and herd management to better suit the dairy cow's requirements, help her to cope in her environment and thereby minimise the impact of external risks on the intrinsic risks that face the modern dairy cow.

Below we discuss the external changeable risks which may be altered.

3.2 Extrinsic risks

We are far from understanding lameness in full and many risks that have been identified through observation and statistical analysis have not been investigated for causality in experimental studies (clinical trials or in the laboratory). Experimental studies can test the hypothesis that removal of the risk leads to a reduction in lameness, these studies provide far stronger evidence of causality than studies of risk per se. A further area for caution in interpretation is that some of the risks identified from observational and intervention studies have been associated with clinical lameness and others with occurrence of foot lesions. There are obvious pragmatic reasons for studying lesions rather than lameness. Lesions are more frequent (80% prevalence) (Manske, 2002) and their severity changes fairly rapidly (Leach, 1998) and so one can study a smaller number of cattle for a short time period and collect a similar amount of data to that collected by studying many cattle over a long period of time to get record lameness events. Using lesions to identify risks for lameness is acceptable if the presence of lesions is a good proxy for risk of lameness. We cannot always be sure of this because there is not necessarily a direct correlation between the size and severity of a lesion and the lameness caused by this lesion (Flower & Weary, 2006; Green & Mülling, 2005).

There are six key areas that we can consider when attempting to reduce lameness in dairy cows. These are listed in Table I with the specific lesions that may be targeted through improved management in these areas. We discuss these areas below.

Table I. **Key areas for external risks and the associated lameness**

Risk area	Effect of good environement/management	Associated lesion in poor environment
Cow comfort Maximising lying times Comfortable lying surface Good walking and standing surfaces	Reduces wear on the sole Reduces pressure on the feet Reduces damage to the bony prominences	Sole ulcer Heel ulcer Laminitis Hock damage/swelling
Cow hygiene Dry environment Slurry free environment Good herd biosecurity	Reduces contact between pathogen and host Prevents introduction of infectious pathogens Reduces exposure of feet to corrosive environment	Digital dermatitis, Heel erosion/interdigital dermatitis Other infectious causes of lameness
Social and physical integration for heifers and dry cows	Reduces defensive movements Avoids cow to cow confrontation Reduces standing times Improves eating and drinking behaviour	White line disease
Cow flow on the farm Good routes around Buildings Parlour To pasture To feed	Allow a cow to express normal gait Reduces defensive movements from humans to avoid confrontation Reduces standing times Improves eating and drinking behaviour	White line disease Sole ulcer
Diet Macronutrients Micronutrients	Reduces ruminal acidosis and macro and micronutrient deficiencies or excesses Improves hoof horn quality and integrity	White line disease Sole ulcer
Correct routine professional functional preventive hoof trimming	Corrects abnormal growth of the hoof horn Prevents excessive/abnormal wear Prevents areas of deep sole horn Interrupts vicious circle of increased horn production Balances the weight load on lateral & medial claw Avoids high loading of localised areas of the sole	All causes of lameness

3.2.1 Cow comfort

Prolonged standing has been associated with the presence of sole ulcers (Cook, *et al.* 2004) and increased foot lesions and lameness (Singh *et al.* 1993b; Leonard *et al.* 1994). It is also reported to reduce the efficiency of rumination, which may impact on diet and exacerbate diet related lamenesses (see below).

Excessive standing may occur for two reasons:

The lying conditions are not comfortable. In this situation cows will lie down for larger time if there is enough lying space; Bowell (2003) reported that the ratio of cubicles to cows was negatively correlated with locomotion score. Cattle will also lie down for longer if lying conditions were comfortable. Longer lying times have been reported in straw yards compared with cubicle houses (Singh *et al.* 1993a) and shallow vs deep quantities of bedding in cubicle houses (Faull *et al.* 1996). Longer lying times have also been observed when cows lie on mattresses compared with mats (Chaplin *et al.* 2000) and on deep sand when compared with mats and sawdust (Cook *et al.* 2004). Hard lying surfaces, which result in cattle bearing weight on a few points of the body, may lead to superficial damage which may in turn discourage cattle from lying down. Wechsler *et al.* (2000) reported a significantly higher incidence of leg injuries over the tarsus (hock) in cows housed in cubicles with mats compared with cubicles bedded with straw. Given a choice, cows preferred cubicles deeply bedded with sawdust or sand to cow mattresses (Tucker *et al.* 2003). Other factors linked with uncomfortable lying conditions include those associated with cubicles; Leonard *et al.* (1994) reported that small Newton Rigg cubicles were associated with decreased lying times and increased haemorrhage scores in cattle when compared with large Dutch comfort cubicles. Faull *et al.* (1996) reported increased locomotion scores associated with limited "borrowing" space at the front and side of cubicles, low side rails and high kerb heights (> 16cm) in the cubicle houses in 37 herds. In summary, cows lie down more when the lying area is comfortable. There are many suggested lying times for cattle. There is probably no absolute since a cow's activity will depend upon her yield, however, cows should not stand while ruminating, and they should lie down at every opportunity.

Poor cow flow, because cattle queue to feed, drink and be milked (see below).

3.2.2 Type and quality floor surfaces

Type of floor surface

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 aetiology of these lesions. Concrete is ubiquitous in most intensive dairy industries and so we cannot assess the impact of concrete without turning to countries where it is not used. Clearly the breeds and production of Kenyan cattle may also vary but the information from this study cannot be ignored. 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 & Bergsten, 2001) and lesions (Webster, 2002). This is hypothesised 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.

Quality of floor surface

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. Smooth walking surfaces have been associated with poor locomotion (Faull *et al.* 1996). 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, 1998), 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. Reduction of excessive standing times prevents prolonged pressure on the weight bearing parts of the claw thus preventing direct damage to the soft living tissue and improving microcirculation in the dermal vascular system required for nutritional and oxygen supply of the horn producing tissue.

Changing lying conditions is in reality highly complex. On farms we are often looking at a combination of stocking density, cubicle type, lying surface, bedding material and depth and possibly even a slurry system that constrains changes in cubicle design and bedding type. This poses two challenges: which of the features of the housing is “causing” the lameness and how can we change only one aspect e.g. recommending sand over sawdust as a bedding material may not be acceptable if the slurry system will not handle sand. This is where the farmer and advisor need to work together to agree a practical solution. Evidence for loss of productivity through premature culling, treatment costs and milk loss may help to persuade a reluctant farmer to consider changing the environment.

3.2.3 Hygiene

A second area for risk of lameness, and indeed any infectious disease, is hygiene. Cleanliness of cows is a good general indicator of hygiene status. Dry feet have greater integrity than wet, the hoof horn and the barrier of the skin between and above the claws is intact reducing the chances of bacteria invading the tissue. In wet conditions, slurry and water, soften the horn and weaken or even disrupt the skin barrier; slurry may also corrode the horn. Lesions associated with exposure to slurry are digital dermatitis and heel erosion (also known as interdigital dermatitis). Somers *et al.* (2005) reported an increased risk of digital dermatitis for cows housed on solid concrete floors compared with those on slatted floors without scrapers. It was also reported that cows with restricted or zero grazing had an increased risk of digital dermatitis, suggesting that both improved cleanliness and reduced stocking may be important factors in reducing digital dermatitis (Somers *et al.* 2005).

3.2.4 Biosecurity

One aspect of hygiene is biosecurity. The evidence to date indicates that digital dermatitis is most easily introduced into a herd through purchase of an infected animal. Maintaining a closed herd at a high level of hygiene is the best way to prevent introduction of infectious lameness or most other infectious diseases. If this is not possible then quarantine for two weeks and careful examination of the lifted and cleaned feet of newly purchased animals will assist in reduction of introduction of new infections.

3.2.5 Social and physical integration

Heifers and dry cows require careful integration into the main herd after calving (Gonzalez *et al.* 2003; Leonard *et al.* 1996). Preparation for this integration needs to begin several weeks before calving. Good integration not only reduces lameness but also reduces other diseases such as mastitis and may prevent loss of body condition (Lamb, 1976). Part of the integration is the gradual adaptation to hard floor surfaces as described above, maybe increasing the time of exposure over weeks rather than making a sudden change. Cattle have a social hierarchy and introduction of heifers and dry cows creates challenges to this hierarchy (Boe & Faeverik, 2003). Most dominant behaviour leads to avoidance by lower ranking cattle. If lower ranking cows can achieve avoidance without:

- standing rather than lying down,
- having reduced access to feed and nutrition and,
- making sudden changes in direction to avoid dominant cows, this will improve their overall health and reduce the risk of physical foot damage (Galindo & Broom, 2000; Huzzey *et al.* 2006).

Similarly, a gradual increase in the energy and protein content of the diet rather than a sudden change will reduce the risk of dietary upset and any consequential associated risks between diet and lameness.

3.2.6 Cow flow

Poor cow flow may arise when there is a poor physical layout on the farm, such that the cows have to negotiate tight turns, experience crowding or queuing or are rapidly funnelled. Poor cow flow also occurs when there is restricted access to feed or water, either an absolute restriction or a functional restriction, because areas of the feed face are blocked by other cows or unattractive to cows to access (Boe & Faerevik, 2003; Huzzey *et al.* 2006). Rough handling e.g. driving with dogs or use of backing gates, lack of space and conflict between cows also often lead to sudden or irregular movements. Turning and twisting on hard and abrasive surfaces (Chesterton *et al.* 1989) can cause damage to the living dermis and horn producing epidermis inside the claw capsule. This soft tissue is sandwiched between the hard pedal bone and the hard cornified claw capsule. Sudden movements expose this tissue to shearing forces under load which is a physical efficient way in which tissue may be damaged or destroyed. The physical design of the housing system can lead to prolonged standing times. Key times when cows may have to stand for unnecessarily long periods include queuing to be milked, queuing to eat, queuing to drink or taking longer than necessary to eat, drink and be milked. This lack of efficiency is important to an animal producing 30-40 kg of milk per day which requires a long time to ruminate and digest the quantity of diet needed to produce such large volumes of milk. Any difference between efficient eating, drinking and milking times and the actual times taken is time when the cow could have been lying down. In this situation, provided the lying area is attractive (see cow comfort above), cows will lie down longer if they can spend less time doing other essential activities. Such good management is associated with a reduced risk of sole ulcer and other horn disorders.

3.2.7 Nutrition

For the modern dairy cow a well-balanced diet with gradual change avoids dietary upset. It takes the rumen flora six weeks to adapt to a sudden diet change and during this time apparent non-essential micro-nutrients as well as macro-nutrients may not be available for absorption at the optimum level. Experiments *in vitro* indicate that high concentrate (> 50% dry matter) rations reduce the bacterial synthesis of biotin in the rumen (DaCosta-Gomez *et al.* 1998). This response may be due to an insufficient conversion of lactate to pyruvate and a reduction in rumen pH associated with high concentrate. Mock (1996) reported that biotin deficiency was related to insufficient pyruvate carboxylase activity, resulting in cellular lactic acidosis. It may be possible that ruminants receiving proportionately high grain diets do not synthesise sufficient biotin in their rumen to convert lactic acid to pyruvate and then oxaloacetate, thus predisposing them to lactic acidosis. Continuous supplemental biotin at 20 mg/cow/day reduced white line disease lameness in cattle from five herds in a within farm clinical trial (Hedges *et al.* 2001). The action of biotin on preventing lameness is biologically plausible because enzymes requiring biotin are responsible for lipogenesis which is required for synthesis of intercellular cementum establishing horn cell adhesion in claw horn (Koester *et al.* 2000). Biotin supplemented cattle have an improved horn cell adhesion. The costs of biotin are now such that it is worth continuously supplementing feeds of dairy cattle to assess its impact in individual herds: effects will take 4-6 months to occur. Nocek (1997) reported that lactic acidosis may contribute to lameness in dairy cows. High starch low fibre diets are associated with a higher incidence of laminitis (inflammation of the corium), sole ulcers, white line lesions and heel erosions (Livesey & Flemming, 1984; Livesey *et al.* 1998; Webster, 2001). It is also hypothesised that the feeding of high energy rations to growing heifers may result in a greater risk of lesions or lameness once they enter the milking herd (Greenough & Vermunt, 1991). There are now studies that indicate that feeding maize silage, associated with acidosis, is associated with raised lameness (Amory *et al.* 2006), particularly "laminitis" and sole ulcers. However, there are also experiments designed to explore the importance of housing, feeding and parturition/lactation which indicate that the structural integrity of connective tissue is most severely compromised by housing in cubicles. Parturition and lactation amplified this effect whereas feeding had no significant influence (Webster, 2001, 2003; Webster *et al.* 2005). In this context it must be re-emphasized that the dermis is exposed to high local mechanical pressure (Hinterhofer *et al.* 2006; van der Tol, 2002), particularly when cows stand for excessively long periods throughout the day. Cubicle housing in comparison to straw yards leads to elevated level of pro MMP2 and active MMP 2 in the connective tissue of the claw (Tarlton *et al.* 2000; Webster *et al.* 2005). According to these hypotheses cow comfort/housing flooring would be major risk factors and their improvement aiming at longer lying times and soft flooring would be of outstanding importance.

3.2.8 Functional hoof trimming

There is still much discussion on the correct approach to trimming cow's feet. It is not clear which approach is best. However, countries and herds where routine foot trimming is used generally report lower incidence of non infectious foot lameness (Manske, 2002). This may be an association, however, given that cattle are designed to walk on pasture-type ground it is not surprising that they need corrective trimming to adjust the foot to a suitable shape when on concrete. However, foot trimming procedures have also been associated with the spread of digital dermatitis and in preventing this spread. Wells *et al.* (1999) reported a decreased risk of digital dermatitis when hoof trimming equipment was washed between cows. Having a hoof trimmer who serviced several units was also associated with an increased risk of digital dermatitis.

4. CONCLUSIONS FOR LAMENESS REDUCTION

We could argue that in 2006 practitioners do not have enough convincing information to attempt to reduce lameness in cows. However, the rate of progress of research on lameness is currently quite rapid and the data a farmer needs to collect will be of increasing value if it is of several years duration. This is because lameness has a slow pathogenesis and identifying patterns of cause will be easier if the information on cattle lameness has been recorded for several years that cows become lame at a certain time of year/lactation for several years. We can consider risks associated with lameness in two ways. Firstly, we can identify the major lesion associated with lameness on a farm and target the known risks, e.g. if a herd has predominantly white line disease lameness in November when cows are 3-5 months in milk we can consider - Where were the cows for the last 4-6 months? Is the cow flow good? Can heifers be bullied? Are there blind ending passages? Do cows turn as they leave the parlour? What is the floor quality? Are there loose stones on walk ways? Does the diet contain sufficient biotin? On any one farm it is unlikely that all possible risks are actual risks but it will on the other hand never be the case that only one risk is causing all the lameness.

Identifying lameness

All of the above is of no use if the farmer and advisers cannot identify lameness. At the moment we consider that the most objective and accessible as that by Sprecher *et al.* (1997), although we have also adapted this (Amory *et al.* 2006) as have others (Cook *et al.* 2005).

Table II. **Management and environment to consider when assessing likely risks for foot lameness**

Area under consideration	Management and environment check….
Lying conditions	Lying area is not overcrowded Cattle stand square to lie down and get up Cows lie down and stand up at the first attempt Cattle lie down and stand without restriction, enough lunging space Cattle lie down comfortably ruminating (cows can stretch their head diagonally forward) Cattle lie with one leg forward (smooth rounded brisket bar, not higher than 10 cm) Cubicle adequate length and width Lying surface is comfortable, weight bearing spread over large area Cows do not have hock damage or other lying lesions Cows are clean Bedding is dry and soft
Good hygiene	Check slurry and water management Clean cows Dry bedding Dry floors Adequate ventilation (part of dryness) No puddles
Cow flow	Any Steps? Any Narrow alleys? Any Blind alleys? Any Sharp turns? Are cows forced to move too fast? Any slippery floors?
Diet	Are cows consistent in body condition score? What is consistency of faeces? Sulphur amino acids Check micro-nutrient supplementation Biotin (20 mg/day) Methionine Zinc B

5. SUMMARY

Lameness in cattle is a clinical sign with a multifactorial aetiology. A focused programme for lameness reduction requires farmers and their advisors to know the main types of lameness occurring in cattle on the farm of interest, to know the seasonal and lactational patterns of lameness and the management and environment of these cattle. In this paper we propose an approach to targeting cattle lameness using the above information together with published and new findings on risks for lameness in cattle to move towards targeted programmes for reduction in lameness. Whilst we still have many questions on the aetiology and pathogenesis of the lesions associated with lameness, research from the last 10 years can assist our understanding and we anticipate that research in the next 10 years will strengthen this understanding so that we can reduce lameness in dairy cows.

6. KEY WORDS

Lameness, risk factor, claw diseases, laminitis, bovine foot, prevention, cow comfort.

7. RESUME

Les facteurs de risque associés aux boiteries chez les vaches laitières et une approche suggérée pour la réduction de claudication. La boiterie chez les vaches laitières est un signe clinique avec une étiologie multifactorielle. Un programme focalisé pour la réduction de claudication a pour condition que les agriculteurs et leurs conseillers connaissent les types principaux des claudications. Il est encore nécessaire qu'ils connaissent précisément les types de boiterie en fonction de la saison et des stades de lactation ainsi que de la gestion et l'environnement. Nous proposons une approche de la boiterie en utilisant l'information ci-dessus avec des résultats édités et nouveaux pour s'orienter vers des programmes visant à réduire les boiteries. Nous avons toujours beaucoup de questions sur l'étiologie et la pathogénie des lésions liées à la boiterie ; la recherche des 10 dernières années peut aider notre compréhension afin réduire efficacement les boiteries des vaches laitières.

8. MOTS CLES

Onglon bovin, maladie des onglons, fourbure, confort de l'animal.

9. ZUSAMMENFASSUNG

Lahmheit bei Milchkühen ist ein klinisches Symptom mit einer multifaktoriellen Ätiologie. Ein gezieltes Programm zur Reduktion von Lahmheiten hat zur Voraussetzung, dass Landwirte und ihre Berater die Hauptarten der Lahmheiten kennen, die bei den Rindern in diesem Betrieb auftreten. Weiterhin ist erforderlich, dass sie die Lahmheitsmuster in Abhängigkeit von Jahreszeit und Laktationsstadium sowie das Management und die Umwelt der Rinder auf dem Betrieb genau kennen. In diese Arbeit empfehlen wir eine Vorgehensweise, bei der die Lahmheiten bei Kühen zielgerichtet angegangen werden, indem die zuvor genannten Informationen zusammen mit bereits publizierten sowie mit neusten Erkenntnissen zu Lahmheitsrisiken verwendet werden, um auf gezielte Programme für die Reduktion der Lahmheitsfälle in Herden hinzuarbeiten. Während wir nach wie vor zahlreiche Fragen zur Ätiologie und Pathogenese der Klauenschäden haben, die mit Lahmheiten vergesellschaftet sind, kann die Forschung der vergangenen 10 Jahre unser Verständnis fördern und wir erwarten, dass die Forschung der kommenden 10 Jahre dieses Verständnis soweit ausbauen und festigen wird, dass wir Lahmheiten bei Milchkühen effizient werden reduzieren können.

10. SCHLÜSSELWÖRTER

Lahmheit, Risikofaktoren, Klauenerkrankungen, Rinderklaue, Klauenrehe, Prävention, Kuhkomfort.

11. RESÚMEN

La cojera en el ganado lechero es un cuadro clínico de etiología múltiple. Un programa enfocado en reducir los niveles de cojeras, requiere un conocimiento por parte del granjero así como del veterinario, de los principales tipos de cojera que se dan en la granja, la estacionalidad climática, los patrones de lactancia y el manejo y entorno del ganado. En esta publicación, se propone un programa que utilizando la información arriba descrita junto con otros aspectos no tan conocidos y con resultados ya publicados y recientes sobre los factores de riesgo, se enfoque hacia la reducción de cojeras. Mientras que todavía nos queda por conocer aspectos sobre la etiología y patogénesis de las lesiones asociadas con la cojera, resultados de los últimos y próximos 10 años nos van a ayudar a mejorar este conocimiento y podemos anticipar que la investigación de los próximos 10 años nos servirá para reducir los niveles de cojeras en el ganado lechero.

12. PALABRAS CLAVES

Cojera, factor de riesgo, enfermedades de la pezuña, laminitas, la pezuña del ganado bovino, prevención, comodidad del ganado bovino.

13. ACKNOWLEDGEMENTS

The authors were members of Lamecow (QLK5-CT-2002-00969), a framework 5 project of the EU aiming to reduce lameness in dairy cows. The authors are solely responsible and the work does not necessarily represent the opinion of the European Communities.

14. REFERENCES

Abel HJ, Immig I *et al.* Effect of increasing dietary concentrate levels on microbial biotin metabolism in the artificial rumen simulation system (RUSITEC). Arch Anim Nutr, 2001; 55:371-376.

Alban L. Lameness in Danish dairy cattle: frequency and possible risk factors. Prev Vet Med, 1995; 22:213-225.

Alban L, Agger JF, Lawson LG. Lameness in tied Danish dairy cattle: the possible influence of housing systems, management, milk yield and prior incidents of lameness. Prev Vet Med, 1996; 29:135-149.

Amory JR, Kloosterman P, Barker ZE *et al.* Risk Factors for Poor Locomotion in Dairy Cattle in Cubicle Housing on Nineteen Farms in The Netherlands. J Dairy Sci, 2006 (in press).

Boe KE, Faerevik G. Grouping and social preferences in calves, heifers, and cows. Appl Anim Behav Sci, 2003; 80:175-190.

Boettcher PJ, Dekkers JC *et al.* Genetic analysis of clinical lameness in dairy cattle. J Dairy Sci, 1998, 81:1148-1156.

Bowell VA, Rennie LJ *et al.* Relationship between building design, management system and dairy cow welfare. Animal Welfare, 2003; 12:547-552

Chaplin SJ, Tierney G *et al.* An evaluation of mattresses and mats in two dairy units. Appl Anim Behav Sci, 2000; 66:263-272.

Chaplin SJ, Ternent HE *et al.* A Comparison of Hoof Lesions and Behaviour in Pregnant and Early Lactation Heifers at Housing. Vet J, 2000; 159:147-153.

Chesterton RN. Linking farm physical conditions, herd management and cow behaviour to the distribution of foot lesions causing lameness in pasture-fed dairy cattle in New Zealand. Proc 13th Int Sympo and 5th Conf on Lameness in Ruminants, 2004; 200-202.

Clarkson MJ, Downham DY *et al.* Incidence and Prevalence of lameness in dairy cattle. Vet Rec, 1996; 138:563-567.

Cook NB, Bennett TB, Nordlund KV. Effect of Free Stall Surface on Daily Activity Patterns in Dairy Cows with Relevance to Lameness Prevalence. J Dairy Sci, 2004, 87:2912-2922.

Cook NB, Bennett TB, Nordlund KV - Monitoring indices of cow comfort in free-stall-housed dairy herds. J Dairy Sci, 2005; 88:3876-3885.

Faull WB, Hughes JW *et al.* Epidemiology of lameness in dairy cattle: The influence and indoor and outdoor walking surfaces. Vet Rec, 1996; 139:130-136.

Faye B, Lescourret F. Environmental Factors Associated with Lameness in Dairy Cattle. Prev Vet Med, 1989; 7:267-287.

Flower, FC, Weary, DM. Effect of hoof pathologies on subjective assessments of dairy cow gait. J Dairy Sci, 2006; 89:139-146.

Galindo F, Broom DM. The relationships between social behaviour of dairy cows and the occurrence of lameness in three herds. Res Vet Sci, 2000; 69:75-79.

Gitau T, McDermott JJ, Mbiuki SM. 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.

Gonzalez M, Yabuta AK, Galindo F. Behaviour and adrenal activity of first parturition and multiparous cows under a competitive situation. Appl Anim Behav Sci, 2003; 83:259-266.

Green LE, Hedges VJ *et al.* The impact of clinical lameness on the milk yield of dairy cows. J Dairy Sci, 2002; 85:2250-2256.

Green L, Mülling CKW. Biotin and lameness. A review. Cattle Pract, 2005; 13(2):145-153.

Greenough PR, Vermunt JJ. Evaluation of Subclinical Laminitis in a Dairy-Herd and Observations on Associated Nutritional and Management Factors. Vet Rec, 1991; 128:11-17.

Hedges VJ, Blowey R *et al.* A longitudinal field trial of the effect of biotin on lameness in dairy cows. J Dairy Sci, 2001; 84:1969-1975.

Hinterhofer C, Ferguson JC *et al.* Slatted floors and solid floors: stress and strain on the bovine hoof capsule analyzed in finite element analysis. J Dairy Sci, 2006; 89(1):155-62.

Hirst WM, French NP *et al.* A mixed-effects time-to-event analysis of the relationship between first-lactation lameness and subsequent lameness in dairy cows in the UK. Prev Vet Med, 2002; 54:191-201.

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

Huzzey JM, DeVries TJ *et al.* Stocking density and feed barrier design affect the feeding and social behaviour of dairy cattle. J Dairy Sci, 2006; 89 (1):126-133.

Knight CH. Lactation and gestation in dairy cows: flexibility avoids nutritional extremes. Proc Nutr Soc, 2001; 60:527-37.

Koenig, S, Sharifi, AR, *et al.* Genetic parameters of claw and foot disorders estimated with logistic models. J Dairy Sci, 2005; 88 (9):3316-3325.

Koester A, Meyer K, *et al.* Effects of biotin supplementation on horn structure and fatty acid pattern in the bovine claw under field conditions. Proc 12t[h] Int Sympo Lameness in Ruminants. Ed. J. K. Shearer, 2002:263-267.

Lamb RC. Relationship between cow behaviour patterns and management systems to reduce stress. J Dairy Sci, 1976; 59:1630-1636.

Leach KA, Logue DN *et al.* Claw lesions in dairy cattle: development of sole and white line haemorrhages during the first lactation. Vet J, 1997; 154:215-225.

Leonard FC, O'Connell J, O'Farrell K. Effect of Different Housing Conditions in Behaviour and Foot Lesions in Friesian Heifers. Vet Rec, 1994; 134:490-494.

Leonard FC, O'Connell JM, O'Farrell, KJ. Effect of overcrowding on claw health in first-calved Friesian heifers. British Vet J, 1996; 152:459-472.

Livesey CT, Fleming FL. Nutritional Influences in Laminitis, Sole Ulcer and Bruised Sole in Friesian Cows. Vet Rec, 1984; 114:510-512.

Livesey CT, Harrington T *et al.* The effect of diet and housing and housing on the development of sole haemorrhages, white line haemorrhages and heel erosions in Holstein heifers. Anim Sci, 1998; 67:9-16.

MacCallum AJ, Knight CH *et al.* Effects of time of year and reproductive state on the proliferation and keratinisation of bovine hoof cells. Vet Rec, 2002; 151:285-9.

Manske T, Hultgren J, Bergsten C. Prevalence and interrelationships of hoof lesions and lameness in Swedish Dairy cows. Prev Vet Med, 2002; 54:247-263.

Manske T, Hultgren J, Bergsten C. The effect of claw trimming on the hoof health of Swedish dairy cattle. Prev Vet Med, 2002; 54:113-129.

Mülling CKW, Bragulla HH *et al.* How structures in bovine hoof epidermis are influenced by nutritional factors. Anat Histol Embryol, 1999; 28:103-108.

Nacambo S, Häsig M *et al.* Difference in length of the metacarpal and metatarsal condyles in claves and the correlation to claw size. Proc 13th Int Sympo on Lameness in Ruminants, 2004:104-106.

O'Callaghan KA, Cripps PJ *et al.* Subjective and objective assessment of pain and discomfort due to lameness in dairy cattle. Animal Welfare, 2003.

Singh SS, Ward WR *et al.* Behaviour of Lame and Normal Dairy-Cows in Cubicles and in a Straw Yard. Vet Rec, 1993 (a); 133:204-208.

Singh SS, Ward WR *et al.* Behaviour of 1st lactation and Adult Dairy Cows While Housed and at a Pasture and it's Relationship with Sole Lesions. Vet Rec, 1993 (b); 133:496-474.

Somers JG, Frankenna CJ *et al.* Risk factors for digital dermatitis in dairy cows kept in cubicle houses in The Netherlands. Prev Vet Med, 2005; 71:11-21.

Sprecher DJ, Hostetler DE, Kaneene JB. A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. Theriogenology, 1997; 47:1179-1187.

Stefanowska J, Swierstra D *et al.* Cow behaviour on a new grooved floor in comparison with a slatted floor, taking claw health into account. Appl Anim Behav Sci, 2001; 71:87-103.

Tarlton JF, Holah DE *et al.* Biomechanical and histopathological changes in the support structures of bovine hooves around the time of first calving. Vet J, 2002; 163:196-204.

Tucker CB, Weary DM. Bedding on Geotextile Mattresses: How Much is Needed to Improve Cow Comfort. J Dairy Sci, 2003; 87:2889-2895.

Tucker CB, Weary DM, Fraser D. Effects of three types of free-stall surfaces on preferences and stall usage by dairy cows. J Dairy Sci, 2003; 86(2):521-529.

Van der Tol PPJ, Metz JHM *et al.* The pressure distribution under the bovine claw during square standing on a flat substrate. J Dairy Sci, 2002; 85:1476-1481.

Vermunt JJ, Greenough PR. Claw conformation of dairy heifers in two management systems. Br Vet J, 1996; 152:321-331.

Webster AJF. Effects of housing practices on the development of foot lesions in dairy heifers in early lactation. Vet Rec, 2002; 151:9-12.

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

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

Wechsler B, Schaub J *et al.* Behaviour and leg injuries in dairy cows kept in cubicle systems with straw bedding or soft lying mats. Appl Anim Behav Sci, 2000; 63:189-197.

Wells SJ, Garber LP, Wagner BA. Papillomatous digital dermatitis and associated risk factors in US dairy herds. Prev Vet Med, 1999; 38:11-24.