Detection of lameness in dairy cattle : behavioural health indicators and use of new technologies

UNIVERISTY OF VETERINARY MEDICINE, BUDAPEST
Department of Animal Hygiene, Herd Health and Mobile Clinic

2021

AUTHOR : Margaux VANBELLE
THESIS SUPERVISOR : JURKOVICH Viktor, senior research fellow, University of Veterinary Medicine, Budapest

SUMMARY

Abstract

Lameness is considered as one of the most costly conditions in dairy cattle. Over the past few years, scientists and engineers have tried to develop many aspects of lameness assessment in dairy farms. The appearance of Precision Livestock Farming and Automated Lameness Development Systems have considerably improved the welfare of the dairy cow. However, farmers need to understand the fundamentals of lameness assessment and the objectives behind those new technologies. Lameness in dairy cattle is still an unfamiliar topic for most farmers and is often set aside when appraising animal welfare. Many studies are working on a practical approach to convince farmers to get acquainted with the concept of lameness assessment and realize its relevance in productivity, overall costs and animal well being. In addition, the reactions, comments, opinions and level of knowlegde of farmers is an essential point to consider when discussing lameness detection options in the dairy environment.

Absztrakt

A sántaság a tejelő szarvasmarhák egyik legköltségesebb betegségének számít. Az elmúlt néhány évben a tudósok és a mérnökök a sántaság értékelésének számos szempontját próbálták kidolgozni a tejtermelő gazdaságokban. A precíziós állattenyésztés és az automatizált sántaságfejlesztési rendszerek megjelenése jelentősen javította a tejelő tehenek jólétét. A gazdáknak azonban meg kell érteniük a sántaságértékelés alapjait és az új technológiák mögött álló célkitűzéseket. A tejelő szarvasmarhák sántasága még mindig ismeretlen téma a legtöbb gazdálkodó számára, és gyakran félreteszik az állatjólét értékelésénél. Számos tanulmány dolgozik egy gyakorlati megközelítésen, hogy meggyőzze a gazdákat, hogy ismerkedjenek meg a sántaság értékelésének fogalmával, és ismerjék fel annak jelentőségét a termelékenység, az összköltségek és az állatok jóléte szempontjából. Ezenkívül a gazdák reakciói, észrevételei, véleménye és ismereteik szintje lényeges szempont, amelyet figyelembe kell venni, amikor a sántaság kimutatásának lehetőségeit tárgyaljuk a tejtermelői környezetben.

Introduction

Lameness is considered to be one of the most economically important disorders of the dairy cow and is very often associated with a large number of parameters such as productivity of the farm (especially milk production), management system, genetics, nutrition, animal welfare, behavior, housing, time activity during the day, etc. With a prevalence reaching the 72%, lameness is undeniably a significant concern in most dairy farms and was the subject of many scientific researches and publications over the past few decades (Van Nuffel *et al.*, 2015).

Over the last few years, the relevance of detection in lameness conditions has been considerably heightened and lameness assessment is now a tremendous element in dairy farming management. A considerable amount of field studies have emerged, all having the same ambition: the earliest and easiest lameness detection tool for farmers with the lowest possible costs. A large number of those tools are nowadays widely used in the daily practice such as the Locomotion scoring system, Welfare Quality protocols, Precision Livestock Farming tools and welfare assessment programs. Some of them are using behavioural health indicators, taking into consideration the well-being and welfare of animals through their general aspect and health, resting position, locomotion as well as their social and individual behaviors. This approach is economical and easy but often controversial in the farming world as competence and rigor are needed to approach the most accurate outcome.

Therefore, modern engineering is the newest trend of lameness assessment debate and investigation. Many researches and engineering companies are willing to develop the most economical and precise system to help farmers getting the earliest assessment protocol, thereby lowering the production losses and treatment costs induced by lameness.

Indeed, farmers are first in line when facing complications linked to the health and productivity of their animals. For this reason, we think that it is essential to consider their opinions, needs, concerns, experiences and feedback when discussing lameness management. As part of our literature review, we have conducted an online survey intended for french and irish dairy farmers mainly, who have shared with us their opinions and feedback about the complexity of lameness detection. By including this survey to our litterature, we hope to reflect a more realistic representation of lameness management in dairy farms.

This work could give a innovative perception on lameness detection in dairy farms, focusing mainly on farmer's opinions and concerns. Therefore, it could help them getting a better interest in lameness management, understanding its importance and finding the best suitable tool.

How can behavioural health indicators and the use of new technologies (or PLFs) in dairy cows help the farmers getting a precise and accessible detection of lameness ?

Material and methods

Our study was based on a questionnaire that was sent to some irish and french dairy farmers throughout a platform called "QuestionPro". We could collect a total of 41 completed questionnaire, and the average time of completion was around 8 minutes. Most of the farmers involved in the study are using a conventional-type milking system, and most of them have between 10 to 25 years of experience. Our questionnaire included MQC-type questions, opened question, videos and feedbacks from farmers. All answers were processed and arranged using the platform "Excel". The questionnaire comprised 4 parts: definition and importance of lameness (general questions); definition of Ethology and its applications in lameness; importance and limits in diagnosing lameness and the growing interest of new technologies in assessing lameness. A total of 50 questions were inquired. The link to access the questionnaire was sent to some farmers by text messages, but most farmers were able to find the link on social medias. The short videos dealing with locomotion scoring and included in our questionnaire were imported from a video made by the channel "Agricultural Business and Policy"at the University of Missouri. Our study was thoroughly based on our questionnaire and additional datas from other studies. All graphs included in this litterature review are based on the answers and results interpreted through our questionnaire.

PART 1: Definition and importance of lameness in the dairy cow and the role of Ethology in its assessment.

1. Definition, major diseases associated with lameness, economical importance.

1.1. Definition and importance of lameness in dairy cattle.

Lameness is often described as being the third most valuable health problem of dairy cattle following fertility issues (first) and mastitis (second), sometimes with a prevalence on farms approaching the 70% (Van Nuffel *et al.*, 2015). The costs may depend on several factors such as the type and extent of lameness, the number and stage of lactation, the housing and daily exercise in farms, the hygiene and veterinary care, as well as a couple of metabolic parameters included in the life of high-yielding cows (nutrition, fertility management, extensive milk production, etc) participating in what we call intensive production system. However, there is still an important lack of information for farmers as regard to the economical impacts of lameness and other serious disorders (Nicole Beusker, 2007). In fact, disorders associated with lameness are more prone to manifest together with a more intensive production and management system, which are nowadays well-exposed with the modern dairy farms.

Lameness is defined as "a deviation from the normal gait caused by lesions, defects, injuries, diseases located somewhere in the limb or the rest of the body, and is accompagnied by pain or discomfort, strategy used by the animal in order to maintain a certain state of comfort or even welfare"(Nicole Beusker, 2007). Lameness is first of all a welfare problem, and this can be observed as an incapacity of dairy cows to cope with their environment and their active life. Indeed, the most important issue in animal welfare of dairy cows is probably that they have a very active life with a tremendous pressure put on production performance (such as high milk-yield and decreased calving to conception period). For this reason, they have to compensate that extra energy with an intensive feeding and often being restraint of natural behaviours like rumination, grazing and time lying down (Nicole Beusker, 2007).

Lameness can also be related to a deviation from the normal locomotor system of the animal, illustrated by pain, impaired movement, alteration of normal gait and posture, and loss of symmetry to complete recumbency as in most severe cases. (Van Nuffel *et al.*, 2015). Therefore, disorders causing lameness are often seen as direct impact on inadequacy of the locomotor system to cooperate with the normal metabolism of the cow and are regularly associated with disorders of the foot, claws and leg. Indeed, about 75% of lameness disorders

originate from the claw (along with the deep digital flexor tendon); foot lesions are responsible for 90% of issues with a 85-90% prevalence on the hind feet (Nicole Beusker, 2007). In addition to it, most lesions are detected on the outer claw when talking about the hind feet and inversely when taking the front feet into consideration. Lameness is often classified depending on infectious and non-infectious issues and may be acute (hours, days) or chronic (weeks, months or even years).

1.2. Brief presentation of most significant lameness disorders in dairy cattle.

Lameness disorders may be classified into infectious (digital dermatitis, interdigital dermatitis or foot rot, interdigital flegmone, heel erosion) and non-infectious (sole ulcer and sole hemorrhage, laminitis, white line disease, eczema, overgrowing, sandcrack…). Furthurmore, we can distinguish injuries caused either by the nervous system (obturator paralysis for example) or by the musculoskeletal system (like fractures, tendonitis and arthritis). Finally, disorders may be unintentionally caused by hoof-trimming, this is the "man made disease". (Van Nuffel *et al.*, 2015). Here is a general overview and summary of the most important lameness conditions.

Digital dermatitis (Hairy warts) is probably the most famous infectious disease causing lameness in cattle and is endemic worldwide. This disorder is caused by a very contagious semi-anaerobic mixed bacterial flora such as *Spirochaetas*, *Treponemas*, *Porphyrimonas*, *Fusobacter necrophorum*, *Bacteriodes nodosus*, *Borrelias*, *Mycoplasma* and others. A important number of factors can participate in development of DD such as feeding troubles, lack of hygiene, stress, etc. This painful inflammation is often accompagnied by pus in the wound and can be seen between the bulbs, the interdigital skin, the front of coronet, the dew claws or even inside the horny shoe (*Digital Dermatitis in Cattle - Musculoskeletal System*, 2015).

Interdigital dermatitis (Stable footrot, slurry heel) is often caused by a very contagious and smelly mixed bacterial infection (*Dichelobacter nodosus* being the most important pathogen) which is able to spread from cow to cow in an anaerobic environment. Bacteria are able to penetrate up to the epidermis of the skin between both digits and can even spread up along the coronary band but can not enter further into the dermis. The consequences are painful inflammation with erosion or ulcer-like lesions (*Interdigital Dermatitis in Cattle - Musculoskeletal System*, no date).

Interdigital phlegmone (Footrot, Foul in the foot) is an acute disorder induced by different mixed bacteria (such as *Fusobacterium necrophorum*, *Prevotella intermedia*, *Staphylococcus aureus*, *Dichelobacter nodosus*, *Trueperella pyogenes*, etc) and characterized by an inflammed skin between the interdigital space with typical foul odor and dorsal or plantar swelling. In most severe cases, the infection can reach the nearby joints (such as the fetlock and hock joints) and may become necrotic, leading to cellulitis in deeper tissues (*Interdigital Phlegmon in Cattle - Musculoskeletal System*, 2015).

Heel erosion (Slurry heel) is a disorder with still fully unknown etiology that is manifested by a modification in the appearance of the bulb's surface of the heel and is not always generating lameness, unless complications evolve. The bacteria *Bacteroides nodosus* may be involved as the infectious cause. It seems to be a more seasonal disease (winter months mostly) and widely affected by the poor hygienic or moist environment in dairy barns, with cows in their peak lactation being more at risk (Nicole Beusker, 2007; *Heel Erosion in Cattle - Musculoskeletal System*, 2015).

Progressing with the non-infectious disorders, **sole ulcer** (*Pododermatitis circumscripta*) is of outmost importance regarding monitoring, costs and prevalence of lameness in dairy herds as it often leads to culling. Dairy cows are at highest risk due to the modern and confined systems used today in dairy farming, with a prevalence reaching the 40%. Sole ulcer is a lesion encircled with hemorrhage, necrosis and pus, and may be the consequence of several factors like overburdening of affected claws, laminitis, digital and interdigital dermatitis, as well as lack of hygiene and management issues. Most often the rear outer claws are affected, and to a lessen extent the front inner cows (where the cow puts more weight) and it can lead to more or less severe lameness, with the corium and horny shoe disconnecting or with the corium being "pushed out" from its typical spot in more severe cases (*Pododermatitis Circumscripta in Cattle - Musculoskeletal System*, 2015).

Together with sole ulcer, **sole hemorrhage** is the most prevalent non-infectious lameness disorder of dairy cows. Often confused with laminitis, sole hemorrhage is diagnosed with its typical red-blood staining of the sole and can make it very fragile with considerable poorer horn quality so trauma can easily occur and be the cause of more serious consequences. Other factors such as poor nutrition management and standing for too long periods on concrete surfaces can also be taking into account in development of sole hemorrhage (*Sole Hemorrhage in Cattle - Musculoskeletal System*, 2015).

Laminitis (or metabolic disorder of the corium) is a feeding and nutrition-related disease and occur as a result of grain overload or most commonly called acidosis. At low rumen pH, all bacteria cannot compete with *Allisonella histaminiformans*, a bacteria which can utilise the abundant dietary histidine (resulting from acidosis) to generate histamine in greater quantities or by the release of endotoxins with the help of other microorganisms (molds and mycotoxins), leading to a damage of the tissues in the hoof and a poor horn quality formation. This disease is also at outmost importance as regards to diagnosis and monitoring of the herd as it predisposes to other serious hoof disorders like white line disease and sole ulcer (*Laminitis in Cattle - Musculoskeletal System*, 2015).

White line disease is a famous disorder in heavy and high-lactating cattle appearing mostly on the outer claws of the hind feet, and manifested by hemorrhage detachment of the abaxial wall from the sole at the level of the white line of the claw. The consequences of this lesion are infection of the corium, hemorrhage and necrosis, and it can lead to ulcers or abscesses if not correctly supervised (*White Line Disease in Cattle - Musculoskeletal System*, 2015).

Finally, we can encounter other forms of non-infectious foot disorders, as well as injuries and trauma of the musculoskeletal and nervous system, but are of minor importance here. Furthermore, the "man-made disease" is an important topic of lameness prevention and will not be mentioned in this review.

We can state that there are a lot of factors that can contribute to the development and progression of foot and claw disorders, but we can group these factors into four main divisions. First, the nutrition is a very important trigger of horn quality and production as it brings all the essential nutrients needed for a healthy claw. Such nutrients are biotin, vitamins (A, D and E), zinc, calcium, phosphorus, copper, etc. Nutrition may also be the cause of claw lesions if not properly managed, principally through ruminal acidosis, the leading cause of laminitis (Cook and Nordlund, 2009). Then, the period of calving is characterised by significant hormonal changes that can participate in the modification in the composition of the connective tissue of the corium and lead to a much weaker resistance of the feet to external stress. Therefore, it is often stated that the calving period is the most important and critical period for development of non-infectious feet disorders as the cow is at its most vulnerable stage, and stressors must be drastically reduced during that time to support and encourage claw health (Cook and Nordlund, 2009; Rouha-Mülleder *et al.*, 2009). The third

factor in our list concerns external trauma, usually occuring as a result of bad management in the herd, critical hygiene protocol, neglected cow confort or too rough and irregular surfaces for the cows to walk on. At last, we must take into consideration a very significant factor which regroups all the infectious agents being involved in claw lesions such as *Fusobacterium necrophorum* (foot rot) or *Treponema* (digital dermatitis) (Cook and Nordlund, 2009). In addition, older animals and cows with a certain number of lactation periods are more predisposed to lameness.

As we stated earlier, lameness is considered as the third most economic issue in disorders of dairy cows. The reason for such costs may include a depression in milk quality and quantity, a reduced nutrition, some cycling troubles (primarily as a result of weight loss and declined DMI) leading to a negative impact on reproduction performances, relevant treatment costs and a significant risk for culling when talking about chronic lameness or severe cases. Indeed, the most severe cases may lead to a dramatic increment in treatment cost and time management (up to three times more than for a milder disorder) (Alsaaod et al., 2019). Here comes the crucial point of early lameness assessment, which can become very significant in reducing the costs, keeping an optimal productivity and improving cow comfort in the farm. Therefore, the main ambition today as regard to claw health in dairy herds is to provide an early and accessible solution to help farmers being as accurate and effective as possible when assessing lameness.

2. Role of Ethology and Welfare in lameness detection: definition, importance and limits.

Ethology is referred as the study of animal behavior under its natural evolutive environment, focused as an evolutionarily adaptative trait (‘Ethology’, 2021). Ethology can be considered as a very fundamental element when assessing lameness. By understanding the normal behavior of dairy cows, we can detect and interpret abnormal behavioral signals associated with lameness. In our study, the goal was to approach four different behavioral health parameter groups: the general aspect and characteristics of the animal, the animal at rest, the animal in movement and the social and individual behavior of animals. Therefore we could investigate the influence that Ethology can have on the well-being of dairy cows and consequently the detection of lameness through the farmers’ opinions and assumptions.

Welfare is defined as “the state of animals regarding their attempts to cope with their environment” (Galindo and Broom, 2002). Nowadays, the importance of animal welfare has considerably grown up into people’s interests and farmers’ way of farming. In fact, there is a progressive change and trend to care more about the well-being of animals in general and to replace the actual intensive farming with more ethical farming systems. Farmers willing to adopt this old-fashioned trend can experience many advantages such as a better cow longevity, reduced treatment costs and abusive use of antimicrobial drugs, increased quality of milk production and a decline in lameness cases (Nicole Beusker, 2007). Unfortunately, adopting such systems does not usually promise an increase in the overall production and can easily be limited for that reason.

During the time of our study, we have asked farmers to give us a general opinion about the concept of Ethology and its limits. Farmers were asked to choose the most relevant definition they could think of about Ethology. The latest revealed that most farmers assumed that Ethology is, therefore, the study of the animal behaviour and that the environment where they evolve has a considerable role in assessing it (Figure 1). We can point out the fact that most farmers consider the dairy farm as a potential environment where dairy cows can evolve and express their characteristic behavioural features.

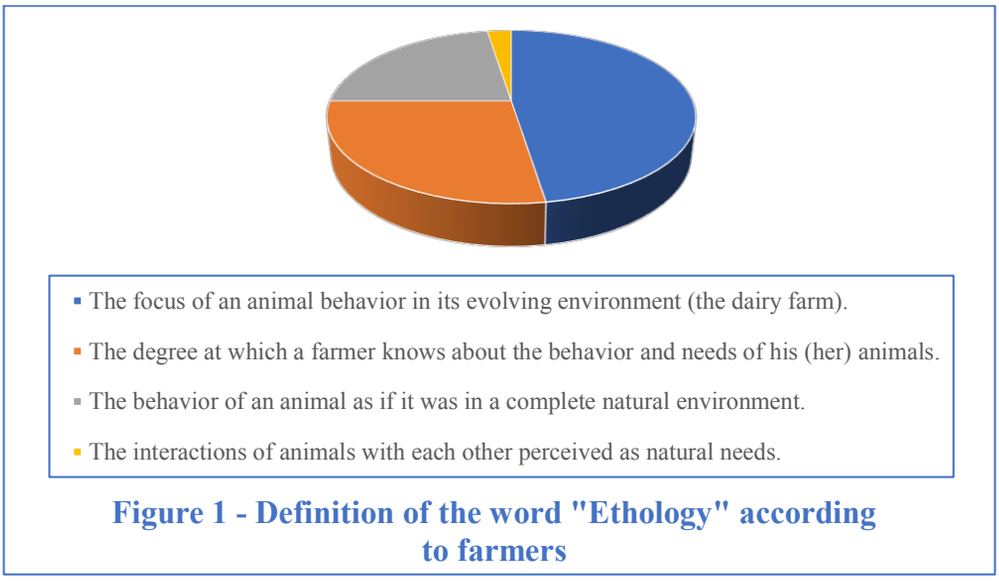


Figure 1 - Definition of the word "Ethology" according to farmers

In addition, most farmers revealed that well-being (85%), as well as the concept of Ethology (51%), was at outmost importance in their dairy farm. In addition, 75% of farmers considered that well-being in farms could improve some conditions as well as the

productivity of dairy cows. However, when we asked them about some alternative methods, new systems and tools they could use to improve well-being, there was two distinct groups. One group already uses such systems and tools such as brushes and rubber mats, and the other group would consider using such tools only if it can have a positive and notifiable impact on the general productivity of dairy cows. We have also asked farmers if they would take into account other peoples' opinions and notably, farmers do give importance to the opinions of consumers and customers (48%), family and friends (58%), other farmers (74%) and professionals such as vets and scientists (95%).

3. The vision of farmers in lameness approach in the daily practice.

The goal of our study was to approach the vision of some irish farmers when discussing lameness detection in their dairy herd. We have questionned dairy farmers from France, UK and Ireland throughout an online survey about their thoughts and feedback considering lameness assessment. A total of 41 farmers generously gave us their opinions so we could interpret and include the results in our review.

Half of the farms included in the survey keep less than a hundred animals and about a quarter of the farms have more than a hundred and fifty cattle. 86.96% of the farmers use the conventional-type of milking system and about 11% of them use a milking robot (Figure 2). Most farmers that did answer our questionnaire have 10 to 20 years of experience with dairy cattle (Figure 3).

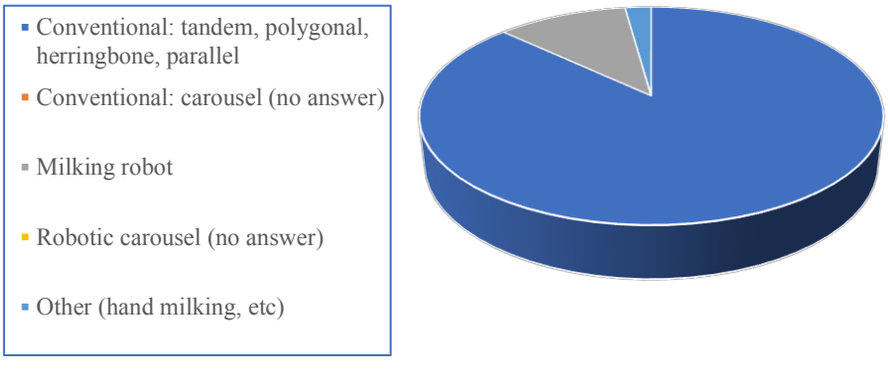


Figure 2 - Types of milking systems used in the farms who participated in the survey.

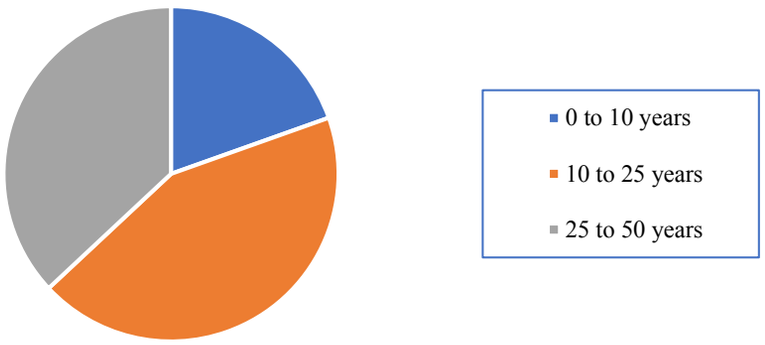


Figure 3 - Years of experience of dairy farmers who answered the survey.

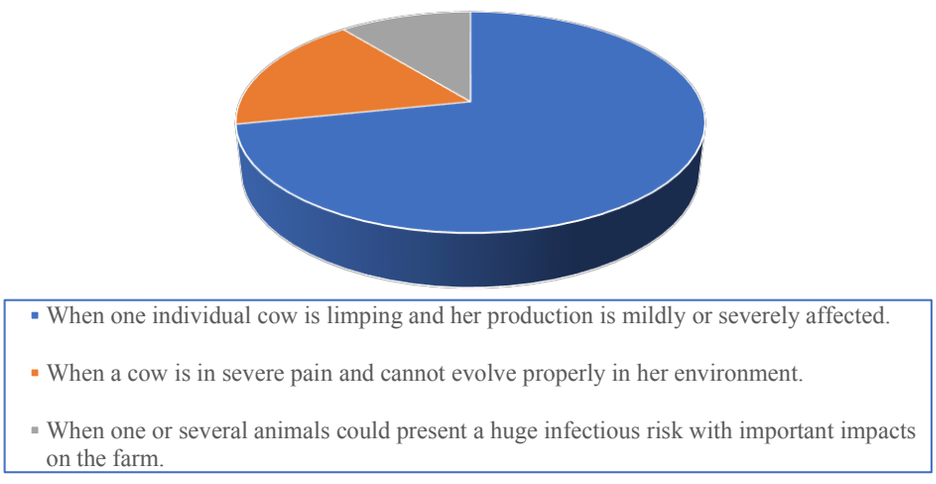


Figure 4 - Closest definition of Lameness according to farmers

The first part of our study aimed to inquire farmers about the definition and importance of lameness in dairy herds (Figure 4). According to farmers, lameness is one of the most costly health problems in dairy cows, equalling mastitis and just prior to fertility issues. Lameness is considered to be at outmost importance for 69.9% of farmers and mainly associated with efficiency and productivity for 59.57% of cases against 36.17% associated with reduced treatment costs, time optimization and satisfaction of a healthy herd. However, all farmers underestimated the overall prevalence of lameness in EU dairy farms. A total of 69.57% of farmers envisaged a 30% prevalence against 30.44% of farmers for a prevalence within a range of 30 to 70% (Figure 5).

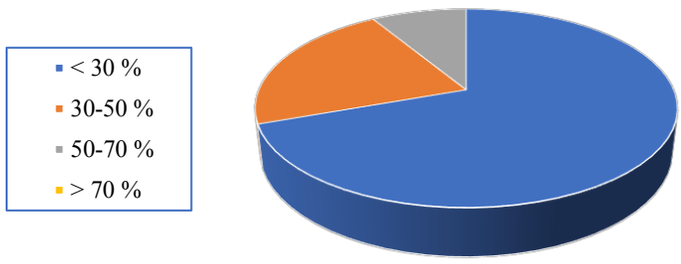


Figure 5 - Farmers guessing the average prevalence of lameness in EU dairy herds.

Most farmers assumed that lameness is at outmost importance at the first stage of lactation (47.83%) and during the periparturient period (32.61%). However, only 6% of farmers considered lameness as the most difficult condition to diagnose in dairy cows. Most farmers assumed that fertility problems (46% of farmers) and acidosis (31%) were the most challenging conditions to assess. Nonetheless, 72% of farmers still agree that lameness assessment is of outmost importance in the dairy cow considering efficiency and productivity.

It is interesting to notice that most farmers did consider lameness as a "normal" situation in dairy cows (Figure 6). Indeed, 74.47% farmers recognized lameness as "normal" considering the genetic influence, old age, feet deformities and taking into account that dairy cattle have to cope with a high and heavy daily milk yield.

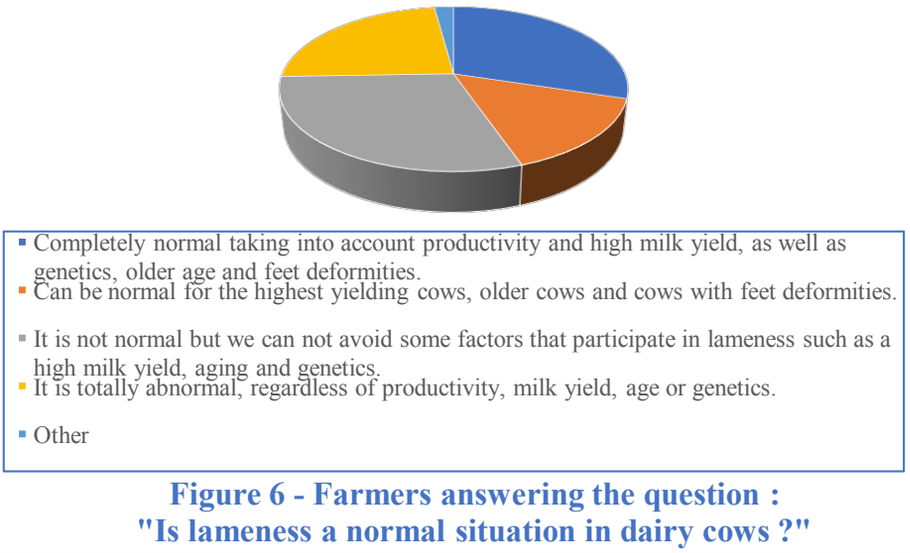


Figure 6 - Farmers answering the question : "Is lameness a normal situation in dairy cows ?"

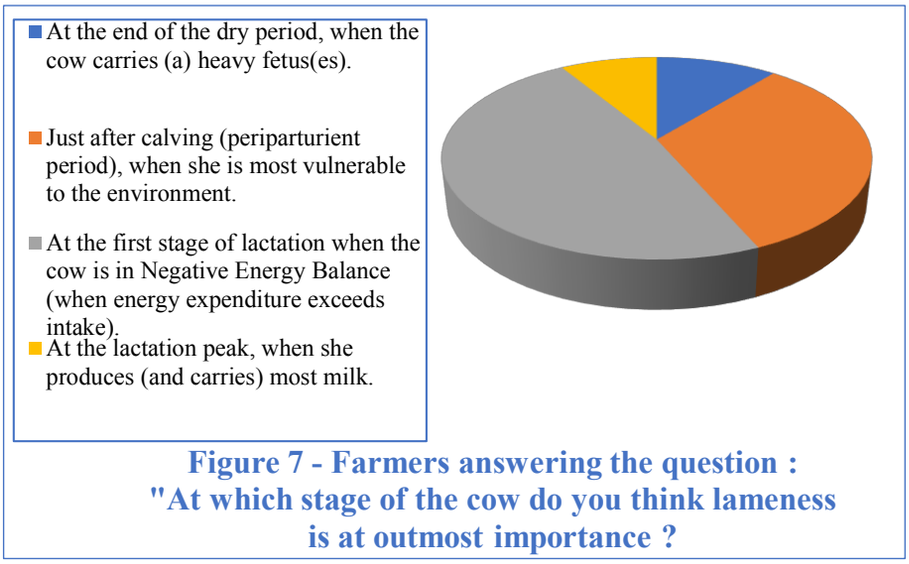


Figure 7 - Farmers answering the question : "At which stage of the cow do you think lameness is at outmost importance ?

It is interesting to mention that the infectious risk pressure regarding lameness is rarely considered as critical and is of smaller importance regarding the condition of lameness according to our results compared to efficiency, productivity and treatment costs. Indeed, only 10.87% of farmers understand that the infectious risk pressure and its impacts on the farm have an important role in the definition of lameness, as well as only 32.61% of farmers take into account the infectious risk pressure during the periparturient period as being at outmost relevance (Figure 7). In addition, 33% of farmers still think that early lameness detection can not have any positive influence on prevention of mastitis. One farmer did mention that a early lameness detection “can stop any serious infections if got in time”. On the other hand, farmers are, for most of them, well acquainted about the positive effects that an early lameness assessment can have on some fertility problems, calving difficulties and metabolic or nutrition-related disorders. One farmer mentionned the word “stress”, which can alleviate the vulnerability of dairy cows to any particular condition.

Finally, we have asked farmers about the stage when they would call a vet or professional for a lame cow. It came out that most farmers (42%) first try to cure the lameness on their own and will only call the vet after a few days if there is no improvement. 24% of farmers will never call the vet for a lame cow but defend the fact that their cows are trimmed at least once a year, and 15% of them will wait until there is an obvious need for treatment. 6% of them will never call a vet for lameness and on the opposite, only 9% of farmers will consult a professional at the very first signs of lameness. This confirms that lameness assessment is fundamental for farmers to understand in order to take a better approach in the process of treatment and prevention, as well as improving the overall well being of cows in the dairy farm.

PART 2: Detection of lameness using behavioural health indicators scoring system.

1. General aspect & characteristics of the animal.

When assessing lameness, a close and deep examination of the animal can be crucial when determining the cause and severity of lameness. Parameters such as claw health, body dirtiness, Body Condition Score (BCS), presence of skin lesions and farm environment may play an important role in the detection of lameness in dairy cows. Indeed, assessing claw health can tell us if a cow may be suffering or not from lameness. Claw overgrowth and skin lesions around the foot are very important factors to consider, both as infectious and non-infectious causes for lameness. Those previous factors, together with body dirtiness, are often connected with the farm environment and can be manifested as an incapability for the cow to freely evolve in it, therefore increasing the risks for lameness (Dembele *et al.*, 2006). It has been proved that continuous trimming would considerably reduce the prevalence of lameness through the preservation of healthy claws. In addition, we can include some other factors being involved in the reduction of the prevalence of lameness. Floor slipperiness and housing quality can be improved by using rubber mats and keeping a good cleaniness and hygiene in the farm. Cow care quality can be assessed by adopting different tools and systems that will be discussed in the last part of our study.

The Body Condition Score, or BCS, is also a crucial factor when assessing lameness in dairy cows. Indeed, BCS and lameness are intrinsically related to each other. Cows with lower BCS (2.5 or less) will generally be more predisposed to lameness than a 3 or 3.5 BCS cow. This could be explained by a reduction of adipose tissue in the digital cushion, causing a weakness in its role and consequently an increased risk for corium injuries. However, a high BCS cannot be acceptable, as the extra body weight puts more pressure on the legs, therefore facilitating disorders caused by overloading (Penev *et al.*, 2012). Farmers are generally aware of the BCS as an outstanding parameter to evaluate the physical condition and well being of the dairy cow. In our study, one farmer stated “A cow with one problem is much more likely to get another problem than a healthy cow. Lame cows lose body condition very quickly and that is often the way other problems start.”

Foot disorders resulting in lameness in dairy cattle are considered to be of outmost importance as regards to animal welfare. Indeed, it can lead to premature cullings in the herd. Longevity can be defined as “a constitutive element of animal welfare” and consequently

may be used as a a useful tool in managing foot disorders and assessing an optimal dairy herd health (Bruijnis et al., 2012).

2. **The animal at rest.**

The animal at rest comprises three important parameters: the time spent lying, the position during lying and the place of lying. Any acceptable assessment of welfare quality of the dairy cow must include the lying parameters. “Time spent lying is considered to be cow’s first priority” (Charlton *et al.*, 2011). In addition, lying time can improve by 25% the blood supply to the mammary glands and gravid uterus. Consequently, cows with an optimal lying time will carry a healthier and faster developed fetus, have a superior milk production and be less susceptible to develop mastitis. This extra time spent lying may have consequences on the nutrition performance of the cow, which may be considerably reduced (Blackie *et al.*, 2011; Van Nuffel *et al.*, 2015). One farmer reported from our study that “lying time vs eating time has massive impact on BCS, metabolic and reproductive systems”.

Some studies have reported that lame cows generally spend time lying down for longer periods in their environment than non-lame cows, especially when lying out of cubicles. Indeed, it has been demonstrated that lame cows tend to spend more time laying out of cubicles than healthy cows (Galindo and Broom, 2002). However, some studies have shown that lame cows could spend more time standing in free stalls than non-lame cows. A significant amount of time spent standing could be associated with pain and incomfort in the hind feet and may result as the so called “Stall standing behavior” which is used by some studies as a “recognized risk factor” for lameness (Cook and Nordlund, 2009). On the opposite, extreme lying time can also be used as a risk factor for lameness. A study has shown that extreme lying time can predict some lameness events, and those animals that have longer periods of time spent lying have more than twice the chance of being lame (Higginson *et al.*, 2010).

A few studies were evaluating some interesting alternatives to the common methods and tools used in the dairy farm nowadays in order to improve and facilitate the animal to rest. Sand has proven to be one of the most promising methods so far. It facilitates both rising and lying down by supporting cushion and traction, so the animal has more stability and is less predisposed to slip or get injured (Cook and Nordlund, 2009).

3. The animal in movement: the locomotion scoring

Assessing the locomotion score in dairy cattle is probably the most practical and economical method to estimate lameness and is widely used nowadays. We can mention six gait attributes that are used for lameness detection: back arch, head bob, tracking-up, joint flexion, asymmetric gait and reluctance to bear weight (Flower and Weary, 2006). Lame cows will tend to have higher assessment scores when evaluating those gait attributes than non-lame cows.

First of all, it has been proven that the time spent walking is significantly reduced, up to 15% decrease in pedometric activity, in lame cows when compared to non-lame cows (Galindo and Broom, 2002). This can be explained by the fact that under normal conditions, the cow puts the majority of her weight to the inner claw of the fore feet and to the outer claw of the hind feet, and the majority of her body weight is supported by the front limb (60% on average). Alterations from this general pattern may reveal lameness and hoof discomfort. Indeed, the stride time, which is the "time when the body weigth is supported by three legs instead of two", is doubled for lame cows if we consider the lame limb as "invalid" (Van Nuffel *et al.*, 2015). In addition, the weights applied to the different limbs (both forelimbs and hindlimbs) have shown to be in direct correlation with the location, type and seriousness of the disorder generating lameness. It has been stated for example that the weigh can be reassigned to the front legs when there is a injury in one or both hind legs. "The more severe the degree of lameness, the clearer the relationship with the body weigth distribution" (Van Nuffel *et al.*, 2015). Several studies agree in the general fact that lame cows "walk slower, have longer stride durations, shorter strides and more uneven weight distribution over limbs" (Van Nuffel *et al.*, 2015). Other parameters such as increased kicking behaviour during milking or last in the milking parlour may also indicate that a particular animal may be in pain due to lameness (Van Nuffel *et al.*, 2015).

We can score lameness according to a four-group classification: aberration of stride, pain-dominated, specific and characteristic lameness (Nicole Beusker, 2007). In our study, we have asked farmers about their opinion and toughts regarding lameness assessment by locomotion scoring. In order to familiarize ourselves with the concept of Locomotion Scoring (LS), we have been using the system adopted by Flower and Weary in a vast majority of their studies on lameness detection in dairy cattle. Here is a review of the Locomotion Scoring system by Flower and Weary:

"LS-1: smooth and fluid movement.

LS-2: imperfect locomotion but ability to move freely is not diminished.

LS-3: capable of locomotion but ability to move freely is compromised.

LS-4: ability to move freely is obviously diminished.

LS-5: ability to move is severely restricted and must be vigorously encouraged to move."

(Blackie *et al.*, 2011)

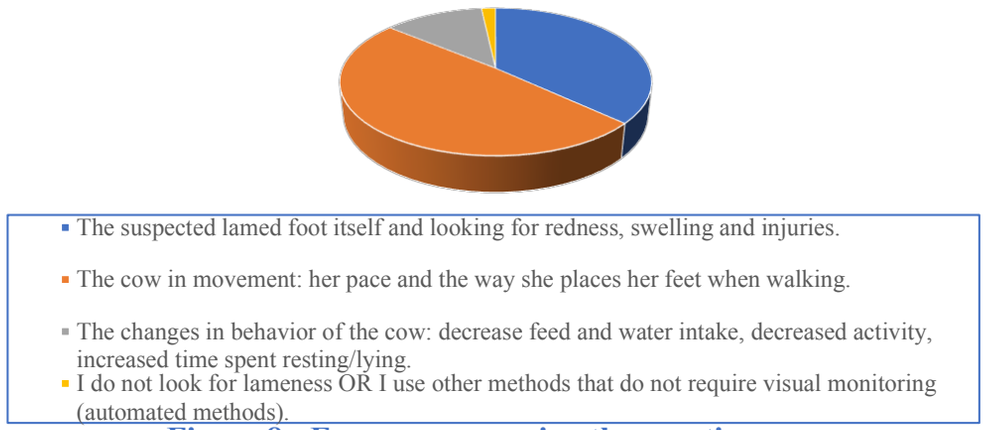


Figure 8 - Farmers answering the question : "What do you look at the most when trying to assess lameness?"

According to our study, a total of 82% of farmers find it hard to dignose lameness and only 18% of them use a locomotion scoring system. 79% of farmers affirm that they do not need such a system to tell wether a cow is lame or not and none of them is using an automated system to measure lameness. Those farmers who are using a visual system for locomotion scoring commonly find it difficult to use. Only 5% of them are comfortable with the idea of visual scoring. 29% of farmers who are not using any locomotion scoring system admit that they do not need such systems and that no extra training can help them improving in lameness scoring. On the other hand, 66% of them would like to know more about the locomotion score and improve their skills in lameness detection. Finally, we have asked the farmers about what they were looking at the most when trying to assess lameness on their own and the most popular answer (49% of them) appeared to be the cow in locomotion, or in orther words the pace and the way she places her feet when walking (Figure 8).

One purpose of our study was to evaluate farmers on grading lameness through a short video using a visual locomotion scoring. Farmers had to watch four short video sequences

and grade the lameness accordingly on a 1 to 5 scale. The video sequences were sampled from a video made by the University of Missouri under the name of "Foremost Dairy Center" who is using a five-point Zinpro scale to assess the locomotion score. Agricultural Business and Policy kindly accepted to let us use their video for educational purposes. Our lameness score in each short video was deeply influenced by the contents present in the video made by the University.

Score 1: normal

Score 2: midly lame

Score 3: moderately lame

Score 4: lame

Score 5: severely lame

The results revealed that it was quite a difficult exercise for farmers. Indeed, most of them were not able to judge the right score, either grading a higher score or a lower one. On average, only 29.5% of farmers did score accordingly to our familiarity with visual assessment of locomotion score. For most of them, farmers did overgrade the lameness score by 1, 2, and sometimes 3 scores above. Interestingly enough, only 18% of farmers were able to score a healthy cow, as the rest of them were giving a score 2 (36%), score 3 (36%) and even score 4 (11%). However, we could not expect a precise interpretation of the results as we would need more participants for the study and further material on lameness scoring.

4. **Social and individual behavior of the cow, the animal coping with its environment.**

Cattle are very sociable animals. The social behavior in dairy cows can be measure using two major parameters, agonistic and non-agonistic interactions, and can reflet wether a cow may or may not be in pain, be prone to have any condition, or suffer from welfare issues such as lameness. Indeed, some articles consider lameness as a "welfare issue", consequently the fact that animals fail to cope with their environment (Galindo and Broom, 2002). Agonistic interactions in dairy cattle are defined as any aggressive behavior towards one or several mates in the herd such as butts to head, neck and ribs; chases and threats. On the opposite, non-agonistic interactions are any sign or attempt to socialize with mates sharing the same environment, such as licks to head, neck, flank and tail; scratches head to head and

head to body (Galindo and Broom, 2002). It appeared from the same study that lame cows were most of the time less likely to start an agonistic interaction and more prone to experience non-agonistic interactions such as a increased time being licked by another cow compared to non-lame cows. However, the lame cows generally endure less favorable experiences in competitive situations, are more susceptible to get injured and have impaired immunity, probably as a result of being in pain (Galindo and Broom, 2002; Dembele *et al.*, 2006). It is interesting to mention that the reason why lame cows tend to receive more non-agonistic interactions, such as being licked for example, can be explained by the tendency of unhealthy cows to improve their discomfort by maintaining positive relationships with their mate in the herd (Galindo and Broom, 2002).

An interesting study has revealed that a lower prevalence of lameness was associated with a longer weaning period of the calf from the dam and a longer cow-calf contact, due to a significant decrease in stress and an increase in essential non-agonistic interactions between the calf and the dam (Rouha-Mülleder *et al.*, 2009). Indeed, the periparturient period is crucial regarding claw health. Around the time of calving, the cow experiences a change in the composition of the connective tissues in the claw, which may "impair the resilience" of the feet to external stressors (Rouha-Mülleder *et al.*, 2009). Avoiding such stress is essential for the dam, therefore good housing quality must be used such as separated boxes, deep stray litter and quiet environement.

When assessing the behavior of the cow, it may be interesting including the interactions with the farmer or stockman. A study reported that using a negative attitude can significantly increase the number of lame animals, and inversely, an increase in positive behavior of the farmer can lower the lameness prevalence in the farm. This is explained by an encouraged locomotion due to more positive emotions, a better blood circulation in the feet and consequently a superior claw health (Rouha-Mülleder *et al.*, 2009).

Finally, it is quite necessary to study the so called "low-resilence behavior" of the cow in its everyday environment, the dairy farm, as we may be able to interpret individual variations in the behavior such as a lowered feeding time or a decreased brush usage. Low-resilience behaviors are non-vital behaviors that significantly drop when the energy ressources involved in one particular activity are limited. For example, when additional brushes were placed in more distant spots in the barn, lame cows tend to use only the ones closest to the water and feed bunk, as a strategy to avoid pain and save energy (Mandel *et al.*, 2018).

PART 3: Modern engineering and Precision Livestock Farming: the goal of the new technologies in detection of lameness.

1. The different tools and systems used in the market or still in progress.

Modern engineering has completely revised the way of assessing lameness in the daily practice. By using different tools, we can get a much more precise diagnosis of lameness for cows that are in pain and show slight variations in their gait or stride, but also for cows that do not necessarily show obvious clinical signs such as limping and other behavioral changes mentioned earlier. The goal of the ALDS, or Automatic Lameness Detection System, is to get an early and accurate detection of lameness and foot pathology, as well as the effects of management strategies and the influence of environmental conditions (Alsaaod et al., 2019). Indeed, farmers usually detect lameness in cattle at most severe stages using visual observation only. The ambition of the ALDS is to help the farmers detecting the earliest possible stages of lameness and consequently increasing the treatment efficiency and reducing the overall costs, including production losses. With the help of trackway measurement (mainly using footprints), we can asset differences in gait, stride length, speed, step length, extent of protraction of hindlimbs, extension of stride and tracking value between lame and non-lame cows. Such systems may show different sensitivity and specificity but must also take into account both the physical and physiological parameters of the dairy cow: body proportions, BCS, nutritional requirements, daily routine, milk production, etc (Telezhenko, 2009).

Continuous claw and feet inspection is apparently the best option when assessing early lameness in the dairy cow. However this is quite unpractical and unachievable in the daily practice (Aland and Banhazi, 2013). In order to face that issue, some precise and accurate tools and methods were developed. The different systems that we find today in the daily practice can be divided into four categories:

1) **Pressure mat-based systems** (*StepMetrix*, *Emfit*, *Gaitwise*), using load-cells or pressure mats. Parameters such as the GRF (or Ground Reaction Forces), dynamical forces, force-time behavior, asymmetry and gait during walking are assessed and use to define if a cow is lame or not. Most studies have shown that the most interesting values for early lameness assessment were the measure of the asymmetry and speed (Van Nuffel *et al.*, 2015). The Gaitwise system, for example, is a pressure-sensitive mat using variables in 4 dimensions (two spatial, one temporal and one related “t” force) to measure the asymmetry

and speed of the cow's gait, both monitored by a time-dependent location of hooves touching the mat. Consequently, two complete gait cycles are measured each time, with a 80% success rate in measurement (including any environmental disturbances) and a gait score comprised between 1 and 3 is assessed depending on the severity of lameness (Bahr *et al.*, 2013). On the other hand, the StepMetrix system evaluate and quantify the ground reaction forces in relation to the duration of each step analysed. The system can therefore determine a unique SMX score for every cow(Bahr *et al.*, 2013). An interesting survey has measured the way cattle may distribute their body weight when using a platform that measures the weight distribution among all 4 legs. In a healthy cow, the frontlegs are carrying most of the weight compared with the hindlegs (60%:40%). When placed in a disagreeable surface, cows can redistribute their weight weather the disagreement comes from the front or back legs. This may explain how lame cows can adapt by reconsidering their whole weight, redistributed predominantly to the contralateral leg (Neveux et al., 2006). This platform can serve as a direct measure of the pain in response to lameness and could already give promising results as to direct relationship between the weight distribution in the lame cow and the evidence of lameness (Neveux et al., 2006).

2) **Camera-based systems** are 2D or 3D video recording systems, with possibility of additional thermal imaging that may support the diagnosis. Several body markers such as the back arch and Body Movement Pattern measure the temporal and spatial gait in vision techniques (Van Nuffel *et al.*, 2015). On the other hand, the increase of temperature in the hoof region can be a significant tool to detect lesions such as Digital Dermatitis and other infectious and non-infectious disorders (Alsaaod et al., 2019). With such systems, we are able to continuously assess and quantify the locomotion and gait datas, without the need for a human presence, with the exception of image and data interpretations. In addition, a interesting number of variables can be assessed such as the step overlap, which tends to be negative in lame cows, and the back arch (Aland and Banhazi, 2013).

Thermal imaging may endorse the assessment of lameness by adding more parameters and specificity into the diagnosis. In any lame cows, thermal imaging would be able to detect any slight increase in surface temperature of the coronary band of the damaged foot, especially the cows that are difficult to detect in earlier stages of lameness. The presence of elevated temperature, with a treshold equivalent to 0.99°C, is often associated to the inflammatory diseases we encounter in lameness such as DD, footrot, ulcers, heel erosion, etc (Alsaaod et al., 2019).

3) **Accelerometer-based systems** (*IceQube*, *IceTag*). They are sensors attached to the animal (generally the neck or legs) that can measure a number of parameters such as the lying and standing behavior in order to monitor the activity and movement of the concerned animal. The sensitivity and specificity of these systems is usually quite significant and can sometimes get close to 90% (de Mol *et al.*, 2013). It was revealed that lame cows experienced asymmetry both in the front and hind legs during acceleration in comparison to healthy cows, so the degree of lameness can be assessed (Alsaaod et al., 2019). It has been proved that accelerometers can detect early signs of lameness by measuring a decreased activity in the cow 7 to 10 days prior to the clinical signs. Indeed, those very sensitive sensors can predict lameness up to 10 days before the appearance of clinical signs. This is explained by the fact that those sensors contain a number of variables, such as the daily milk yield, the neck activity level or the ruminating time, which are best correlated with lameness. In addition, such tools can also assess the lying and standing behavior, which can be a good alternative to straight behavioural observations by the farmer (Van Nuffel *et al.*, 2015). Lame cows tend to have a higher asymmetry of variance, a higher assymmetry of weight and a greater variability in weight applied for both front and hind limbs during acceleration compared to healthy cows (Alsaaod et al., 2019).

4) **Alternative methods**, or use of additional datas such as milk yield, feed intake, rumination and neck activity.

The most important factors to consider for farmers when using an automated system are the economic value and the performance of the system. Farmers want to know if such systems can make a difference in the total lameness costs like treatment, prevention and diagnosis. However, we must take into consideration the experience and technical level of the farmer, as it may involve false positive or false negative results. Therefore, such systems must be well-adapted to farmers, have a good enough performance to counterbalance the costs and must be easy to use (Van De Gucht et al., 2018). Furthermore, we must not completely forget the locomotion score, who should always be used as a “gold standard” or “reference” in lameness assessment (Van Nuffel *et al.*, 2015).

It has been stated that such systems performed well in assessing lameness at the earliest stages or associated with specific lesions, however it turned out that joint problems were better detecting using the visual locomotion scoring system (Van Nuffel *et al.*, 2015). An interesting survey has measured the way cattle may distribute their body weight when using

a platform that measures the weight distribution among all 4 legs. In a healthy cow, the frontlegs are carrying most of the weight compared with the hindlegs (60%:40%). When placed in a disagreeable surface, cows can redistribute their weight weather the disagreement comes from the front or back legs. This may explain how lame cows can adapt by reconsidering their whole weight, redistributed predominantly to the contralateral leg (Neveux et al., 2006). This platform can serve as a direct measure of the pain in response to lameness and could already give promising results as to direct relationship between the weight distribution in the lame cow and the evidence of lameness (Neveux et al., 2006).

2. **Pros and cons of such tools/systems (success rate and economical value).**

Lameness is a condition that can be very expensive to manage. We estimate the costs of lameness per cow per year being close to 70 euros. It has been assumed that treated cases were in general less expensive than untreated lameness cases (Van De Gucht *et al.*, 2018). One of the main influencing factors for farmers when adopting PLF tools is the "perceived economic return", which can be significant especially in big dairy herds (Van De Gucht *et al.*, 2017). The main advantage of ALDS is a prompt and easy detection of lameness, but the PLF tools may have several other interests such as the supervision of claw health, hoof disorders, and the influence of external factors like the environment and the different housing and milking systems. When evaluating the pros and cons of such systems, we need to include some parameters such as the specificity and sensitivity, the investment, the return on investment, the efficacy, the detection performance, herd size, discount rate and system lifespan. Thoses parameters may have a huge influence on economic value. Indeed, the "lameness prevalence influences the economic value", it is therefore important to get a decent estimation of on-farm prevalence prior to choose the adequate ALDS (Van De Gucht *et al.*, 2018). The value of an ALDS, visual or automatic, depends on its detection performance, consequently leading to reduced costs when lameness is assessed promptly (Van De Gucht *et al.*, 2018).

The StepMetrix system, which is part of the pressure mat-based systems, has a high specificity (93.8%) but a relatively low sensitivity (22.2%), therefore many lameness conditions are still not properly detected using this system and it is assumed that visual locomotion scoring is still prefered in most cases (Bahr *et al.*, 2013). The system measuring the Leg Weight Ratio (LWR), by definition the asymmetry in weight distribution between

all legs using load cells, happened to have the highest sensitivity and specificity (superior to 96%). (Van Nuffel *et al.*, 2015). The Gaitwise system had both good sensitivity (84.75%) and specificity (90.5%) on average depending on different gait variables used by some studies (Van Nuffel *et al.*, 2015).

The camera-based systems, associated with a manual locomotion scoring system, may give lots of advantages and promising results but are not fully automatised yet. As part of it, the "back arch" system revealed to be 96% correct on locomotion score assessments. However, the 2D cameras have already been exceeded by the newly arrived 3D camera systems which had even more promising results, up to 90% accuracy (Van Nuffel *et al.*, 2015).

The accelerometer-based systems, such as the Iceqube and the IceTag, can reach 76% accuracy when using behavioral parameters. Moreover, accelerometers measuring the lying time were also very rigorous, showing a similarity of 96.3% to typical lying and standing behavior (Van Nuffel *et al.*, 2015). Another study showed that the IceQube system reached 85.5% sensitivity and 88.8% specificity, even if the performance of the sensorswas still not optimal (de Mol *et al.*, 2013).

Regarding the alternative methods, the specificity for those systems approached the 80%. However the detection performance was only about 50% accurate. On the other hand, some systems based on the milk yield and feeding datas showed more promising results, reaching up to 86% sensitivity and 89% specificity (Van Nuffel *et al.*, 2015).

However, the current ALDS performances could involve a high number of false positives, for example farmers perceiving true-positive cases for midly lame cows as non lame. For this reason, also combined with a decreased eagerness of farmers using ALDS, it is essential to consider improving the actual detection performances in lameness assessment before extensive commercialisation on the market. Within all parameters described earlier, the system's performance is undeniably the most important one. "The better the detection performance, the higher the potential avoided losses" (Van De Gucht *et al.*, 2018). In conclusion, the actual automatic detection performances may need some improvements in order to increase their cost effectiveness and justify their profitable effects on animal welfare (Van De Gucht *et al.*, 2018).

3. The opinion and feedback of farmers on Precision Livestock Farming (PLF) tools used in lameness assessment.

The opinion and feedback of farmers on PLF tools is an important part of our study, as it can reveal what farmers think about lameness assessment and how familiar they are with the new technologies and tools in the market. “Farmers usually detect only one in four severely lame cows when compared with expert scoring” (Van De Gucht *et al.*, 2018). A recent study has shown that the two main drivers for improving claw and foot health in dairy cows were an increase in milk production and an amelioration in animal welfare (Dutton-Regester *et al.*, 2019). It is also important to highlight the relevance of the language used by farmers to describe lameness. Indeed, farmers may use a large variety of terms to describe cow locomotion, and scientists dealing with farmers must adapt to that contrast.

According to our study, only 38.24% of farmers are using PLF tools in their farm. However, we must consider the fact that our study was only limited to some countries, Ireland and France, where the dairy herds are of small to moderate size compared to some global powers such as New Zealand and the USA. The most popular tool used within those farmers is the heat detection collar, followed by the tail-mounted calving sensor (or *Moocall*). A recent study revealed the farmers’ preference for automatic lameness detection. It has been stated that farmers that already use one PLF tool were more likely to try using an ALDS. However, according to our study, most farmers that did not use any PLF system before are now tempted to try using them in the near future. Nowadays, in small dairy herds, many farmers do not use any ALDS tool. Our study showed that 6% of farmers use a camera-based system and only 3% of them a pressure mat-based system. When asking to farmers the question of a possible future use of such ALDS, 31% of farmers are not favorable to the idea of adopting such system (Figure 9). However, it is interesting to highlight the important role of education and information given to farmers, as it can lead to an increased attractivity for ALDS. Indeed, 22% of farmers would probably try such systems if they knew more about their existence and use. On the other hand, 44% of farmers are still not convinced that ALDS should be introduced in their farm, and for different reasons such as extensive costs, no help needed to assess lameness or unfamiliarity with new technologies. 31% of farmers affirm that they do not need any help to tell them wether one of his/her cow is lame or not (Figure 9). “Many farmers viewed mobility scoring as unnecessary because they felt that they were able to detect lame cows in their normal working practices” (Horseman *et al.*, 2014). One of

the farmers that participated in our study stated “I do know my cows very well and I do not need any tool to detect lameness”.

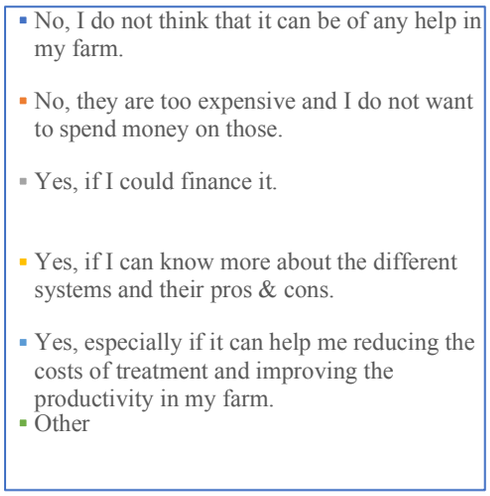
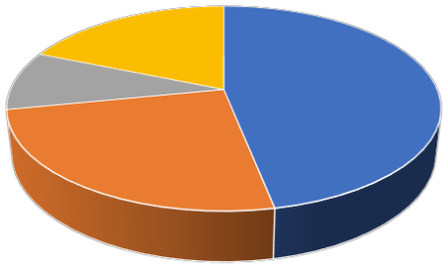


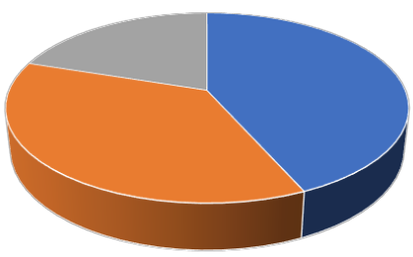
Figure 9 - Farmers answering the question : "Would you invest in an automatized system for lameness assessment?"

Farmers generally preferred the accelerometer-based systems, followed by the pressure mat-based systems, and finally the camera-based systems (Van De Gucht *et al.*, 2017). The most important features for farmers regarding lameness assessment using PLFs were the total investment, the return on investment and the system performance. When asking farmers about the most important elements in the adoption of such tools, most of them elected the costs, total investment and return on investment (43%); followed by the system performance, accuracy and longevity over time (37%), and finally monitoring and support in lameness management (20%). As reported by another study, “costs may be a potential barrier for farmers” (Dutton-Regester *et al.*, 2019). According to our study, the best advantage of ALDS for farmers would be an improvement of productivity (47%), followed by a better gestion of time (25%). Both the reduced veterinary costs and the improvement of well-being represents only 28% in the farmers’ choices (Figure 10). Those results clearly tell us that the costs are not always the most important parameter, when the productivity and return on investment fulfill the expected demand and requirements (Figure 11).



- Productivity!: to be able to detect any lame cow, so a better performance in the farm.
- Time!: a prompt detection of lameness means less time spent to cure it.
- Costs!: an early detection means reduced veterinary costs.
- Well-being!: to improve the overall well-being of cows.

Figure 10 - Farmers answering the question : "What would be the best advantage of such systems in the daily practice ?"



- Option 1: costs, total investment and return on investment.
- Option 2: system performance, accuracy and longevity over time.
- Option 3: monitoring and support in lameness management

Figure 11 - Farmers answering the question : "What would be the most important element for you in the adoption of such systems ?"

Farmers generally preferred the visual assessment compared to the automatic lameness assessment. However, this preference was reversed when they were informed about the importance in early lameness assessment and the consequences of a later detection (Van De Gucht *et al.*, 2017). This emphasize the fact that information and education is key in helping farmers getting a better lameness management in their farm. Indeed, by supporting and informing farmers about lameness and its consequences, we can encourage them to evolve in their lameness management, which is still underestimated in most agricultural colleges and this could explain most of the serious consequences we know on how farmers deal with

this condition. In addition, a study showed that when farmers were informed about the importance of lameness and the possible consequences of poor farm management, they were willing to make efforts and improve their awareness for animal welfare and lameness. Therefore, it seemed to have direct consequences on decreasing prevalence and treatment costs (Horseman *et al.*, 2014). The same study emphasized the importance of "job satisfaction" when farmers were able to detect early signs of lameness, establish prompt treatments, and finally appreciating some improvements in cow's locomotion (Horseman *et al.*, 2014).

Conclusion

In conclusion, lameness is an important welfare issue in dairy farms, and most farmers are aware about the consequences it may lead to, if not properly handled. Indeed, ethology and lameness are intrinsically related to each other, and ethology must be considered as fundamental when assessing lameness. It has been revealed that all common lameness detection methods had in common the study of animal behavior, assessed by a large number of parameters that were mentioned earlier. Our study has shown that detection of lameness is not an easy task, and that there is not a best way to assess it. Each detection method has its pros and cons and may or not be suitable for farmers. We assumed that the behavioural methods were probably the less invasive and costly approaches, but needed a complete understanding of the cow's physiology and ethology, and probably not being able to catch the earliest signs of lameness. The PLF tools revealed to be more specific and sensitive, and able to recognise the most primitive stages of lameness, but could be very expensive for farmers, as well as invasive and uneasy to use. According to our study, the assessment of locomotion scoring may be the most accurate method nowadays, but requires meticulous practice and experience.

Farmers are well aware that lameness is a critical condition regarding productivity and welfare, and our study revealed that most of them do consider improving animal well being in their farm. The principal motivations for farmers regarding welfare enrichement are an amelioration in productivity, a decrease in treatment costs and a better time management. It was assumed that most french and irish farmers are still unprepared to switch to the new ALDS tools for many reasons such as lack of investment costs, too small farm size, shortage of knowledge and lack of interest.

Finally, our study exposed the lack of education and information farmers are facing regarding conditions in dairy cattle, especially lameness. Indeed, lameness is not considered as an important topic in most agricultural courses, and most farmers are ignorant about its consequences on farm productivity, animal well-being and overall costs. ALDS tools may only be useful if farmers understand the relevance of such a condition and its interests for the farm. Therefore, information must act as an important role in the farmers' education regarding most conditions in dairy cows, such as proper courses included in agricultural degrees, improved discussions with vets and professionals, and regular presentations of innovations through meetings, webinars, articles, adds, etc.

References

Alsaaod M, Fadul M, Steiner A (2019) Automatic lameness detection in cattle. The Veterinary Journal, 246, 35–44. https://doi:10.1016/j.tvjl.2019.01.005

Blackie N, Amory J, Bleach E, Scaife (2011) The effect of lameness on lying behaviour of zero grazed Holstein dairy cattle. Applied Animal Behaviour Science, 134(3), 85–91. https://doi:10.1016/j.applanim.2011.08.004

Bahr C, Van Nuffel A, Van Weyenberg S, Berckmans D (2013) The ease of movement: how automatic gait and posture analysis can contribute to early lameness detection in dairy cattle. Livestock housing: modern management to ensure optimal health and welfare of farm animals, 12. https://doi:10.3920/978-90-8686-771-4_22

Charlton G L, Mark Rutter S, East M, Sinclair L A (2011) Preference of dairy cows: Indoor cubicle housing with access to a total mixed ration vs. access to pasture. Applied Animal Behaviour Science, 130(1), 1–9. https://doi:10.1016/j.applanim.2010.11.018

Cook N B, Nordlund K V (2009) The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. Veterinary Journal, 179(3), 360–369. https://doi:10.1016/j.tvjl.2007.09.016

Digital Dermatitis in Cattle - Musculoskeletal System (2015) *Veterinary Manual*. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/digital-dermatitis-in-cattle?query=digital%20dermatitis. Accessed 25 January 2021

Dutton-Regester K J, Wright J D, Rabiee A R, Barnes T S (2019) Understanding dairy farmer intentions to make improvements to their management practices of foot lesions causing lameness in dairy cows. Preventive Veterinary Medicine, 171, 104767. https://doi:10.1016/j.prevetmed.2019.104767

Ethology (2021) *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Ethology&oldid=1002599359. Accessed 20 February 2021

Flower F C, Weary D M (2006) Effect of Hoof Pathologies on Subjective Assessments of Dairy Cow Gait. Journal of Dairy Science, 89(1), 139–146. https://doi:10.3168/jds.S0022-0302(06)72077-X

Galindo F, Broom D M (2002) The Effects of Lameness on Social and Individual Behavior of Dairy Cows. Journal of Applied Animal Welfare Science, 5(3), 193–201. https://doi:10.1207/S15327604JAWS0503_03

Heel Erosion in Cattle - Musculoskeletal System (2015) Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/heel-erosion-in-cattle?query=heel%20erosion. Accessed 26 January 2021

Higginson J H, Millman S T, Leslie K E, Kelton D F (2010) Validation of a New Pedometry System for Use in Behavioural Research and Lameness Detection in Dairy Cattle. Proc. First North Am. Conf. Precision Dairy Management

Horseman S V, Roe E J, Huxley J N, Bell N J, Mason C S, Whay H R (2014) The use of in-depth interviews to understand the process of treating lame dairy cows from the farmers' perspective. Animal Welfare, 23(2), 157–165. https;//doi:10.7120/09627286.23.2.157

Dembele I, Spinka M, Stehulova I, Panama J, Firla P (2006) Factors contributing to the incidence and prevalence of lameness on Czech dairy farms. Czech Journal of Animal Science, 51(3), 102–109

Interdigital Dermatitis in Cattle - Musculoskeletal System (2015) Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/interdigital-dermatitis-in-cattle?query=interdigital%20dermatitis. Accessed 25 January 2021

Interdigital Phlegmon in Cattle - Musculoskeletal System (2015) Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/interdigital-phlegmon-in-cattle?query=interdigital%20phlegmon. Accessed 25 January 2021

Laminitis in Cattle - Musculoskeletal System (2015) Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/laminitis-in-cattle?query=laminitis. Accessed 26 January 2021

Bruijnis M R N, Meijboom F L B, Stassen E N (2012) Longevity as an Animal Welfare Issue Applied to the Case of Foot Disorders in Dairy Cattle. Journal of Agricultural and Environmental Ethics, 26, 191–205. https://doi:10.1007/s10806-012-9376-0

Mandel R, Harazy H, Gygax L, Nicol C J, Ben-David A, Whay H R, Klement E (2018) Short communication: Detection of lameness in dairy cows using a grooming device. Journal of Dairy Science, 101(2), 1511–1517. https://doi:10.3168/jds.2017-13207

De Mol R M, André G, Bleumer E J B, Van Der Werf J T N, De Haas Y, Van Reenen C G (2013) Applicability of day-to-day variation in behavior for the automated detection of lameness in dairy cows. Journal of Dairy Science, 96(6), 3703–3712. https://doi:10.3168/jds.2012-6305

Beusker N (2007) Welfare of Dairy Cows: Lameness in Cattle – A Literature Review. Hannover

Pododermatitis Circumscripta in Cattle - Musculoskeletal System (2015) Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/pododermatitis-circumscripta-in-cattle?query=sole%20ulcer. Accessed 26 January 2021

Rouha-Mülleder C, Iben C, Wagner E, Laaha G, Troxler J, Waiblinger S (2009) Relative importance of factors influencing the prevalence of lameness in Austrian cubicle loose-housed dairy cows. Preventive Veterinary Medicine, 92(1), 123–133. https://doi:10.1016/j.prevetmed.2009.07.008

Sole Hemorrhage in Cattle - Musculoskeletal System (2015) Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/sole-hemorrhage-in-cattle?query=sole%20hemorrhage. Accessed 26 January 2021

Penev T, Mitev J, Iliev A, Borisov I, Miteva T, Gergovska Z, Uzunova K (2012) Hygienic and technological conditions favouring lameness in dairy cows: a review. Revue de Médecine Vétérinaire, 163(11), 499–504

Van De Gucht T, Saeys W, Van Nuffel A, Pluym L, Piccart K, Lauwers L, Vangeyte J, Van Weyenberg S (2017) Farmers' preferences for automatic lameness-detection systems in dairy cattle. Journal of Dairy Science, 100(7), 5746–5757. https://doi:10.3168/jds.2016-12285

Van De Gucht T, Saeys W, Van Meensel J, Van Nuffel A, Vangeyte J, Lauwers L (2018) Farm-specific economic value of automatic lameness detection systems in dairy cattle: From concepts to operational simulations. Journal of Dairy Science, 101(1), 637–648. https://doi:10.3168/jds.2017-12867

Van Nuffel A, Zwertvaegher I, Pluym L, Van Weyenberg S, Thorup V M, Pastell M, Sonck B, Saeys W (2015) Lameness Detection in Dairy Cows: Part 1. How to Distinguish between Non-Lame and Lame Cows Based on Differences in Locomotion or Behavior. Animals, 5(3), 838–860. https://doi:10.3390/ani5030387

Van Nuffel A, Zwertvaegher I, Van Weyenberg S, Pastell M, Thorup V M, Bahr C, Sonck B, Saeys W (2015) Lameness Detection in Dairy Cows: Part 2. Use of Sensors to Automatically Register Changes in Locomotion or Behavior. Animals, 5(3), 861–885. https://doi:10.3390/ani5030388

White Line Disease in Cattle - Musculoskeletal System (2015) Veterinary Manual. https://www.msdvetmanual.com/musculoskeletal-system/lameness-in-cattle/white-line-disease-in-cattle?query=white%20line%20disease. Accessed 26 January 2021

Alsaaod M, Fadul M, Steiner A (2019) automatic lameness detection in cattle. The veterinary journal, 246, 35–44. https://doi:10.1016/j.tvjl.2019.01.005

Neveux S, Weary D M, Rushen J, Von Keyserlingk M A G, De Passillé A M (2006) Hoof Discomfort Changes How Dairy Cattle Distribute Their Body Weight. Journal of dairy science, 89(7), 2503–2509. https://doi:10.3168/jds.S0022-0302(06)72325-6

Welfare Quality (2009) Welfare Quality assessment protocol for cattle. Welfare Quality Consortium, Lelystad, Netherlands

HuVetA

ELECTRONIC LICENSE AGREEMENT AND COPYRIGHT DECLARATION*

Name: MARGAUX VANBELLE

Contact information (e-mail): margauxvanbelle@gmail.com

Title of document (to be uploaded): Detection of lameness in dairy cattle : behavioural health indicators and use of new technologies

Publication data of document: .....

Number of files submitted: 2

By accepting the present agreement the author or copyright owner grants non-exclusive license to HuVetA over the above mentioned document (including its abstract) to be converted to copy protected PDF format without changing its content, in order to archive, reproduce, and make accessible under the conditions specified below.

The author agrees that HuVetA may store more than one copy (accessible only to HuVetA administrators) of the licensed document exclusively for purposes of secure storage and backup, if necessary.

You state that the submission is your original work, and that you have the right to grant the rights contained in this license. You also state that your submission does not, to the best of your knowledge, infringe upon anyone's copyright. If the document has parts which you are not the copyright owner of, you have to indicate that you have obtained unrestricted permission from the copyright owner to grant the rights required by this Agreement, and that any such third-party owned material is clearly identified and acknowledged within the text of the licensed document.

The copyright owner defines the scope of access to the document stored in HuVetA as follows (**mark the appropriate box with an X)** :

- [x] I grant unlimited online access,
- [ ] I grant access only through the intranet (IP range) of the University of Veterinary Medicine,
- [ ] I grant access only on one dedicated computer at the Ferenc Hutÿra Library,
- [ ] I grant unlimited online access only to the bibliographic data and abstract of the document.

Please, define the **in-house accessibility of the document** by marking the below box with an **X** :

☒ I grant in-house access (namely, reading the hard copy version of the document) at the Library.

If the preparation of the document to be uploaded was supported or sponsored by a firm or an organization, you also declare that you are entitled to sign the present Agreement concerning the document.

The operators of HuVetA do not assume any legal liability or responsibility towards the author/copyright holder/organizations in case somebody uses the material legally uploaded to HuVetA in a way that is unlawful.

Date: Budapest, ...16…day …11…...month…2021...year

Author/copyright owner signature

HuVetA Magyar Állatorvos-tudományi Archívum – Hungarian Veterinary Archive *is an online veterinary repository operated by the Ferenc Hutÿra Library, Archives and Museum. It is an electronic knowledge base which aims to collect, organize, store documents regarding Hungarian veterinary science and history, and make them searchable and accessible in line with current legal requirements and regulations.*

HuVetA relies on the latest technology in order to provide easy searchability (by search engines, as well) and access to the full text document, whenever possible.
Based on the above, HuVetA aims to:

- *increase awareness of Hungarian veterinary science not only in Hungary, but also internationally;*
- *increase citation numbers of publications authored by Hungarian veterinarians, thus improve the impact factor of Hungarian veterinary journals;*
- *present the knowledge base of the University of Veterinary Medicine Budapest and its partners in a focussed way in order to improve the prestige of the Hungarian veterinary profession, and the competitiveness of the organizations in question;*
- *facilitate professional relations and collaboration;*
- *support open access.*