Lameness around parturation in Dairy Cows:

Its Significance and Ways to Predict it

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Introduction

Lameness of dairy cows is among the most pressing challenges to the dairy sector (Garvey 2022) and has been described as "an ongoing concern of great relevance to animal welfare and productivity in modern dairy production" (Oehm et al. 2019). Locomotive disorders, they may have an orthopaedic, infectious or of a metabolic cause, are a threat to animal health and welfare, they pose an economic threat and not the least a risk for the perception of the sector as a whole (Thomsen et al. 2023b). However, it is generally believed that farmers fail to perceive lameness as a threat to their business (Dutton-Regester et al. 2020).

The Significance of Lameness

In terms of productivity, its effect is comparable to udder health problems (Booth et al. 2004). The economic relevance of lameness derives from various factors: Obviously, lameness is a frequent cause for premature culling of dairy cows (Shearer et al. 2017). Booth et al. (2004) were able to show that diagnosis of a locomotive disorder, i.e., cows being lame, significantly reduced their survival time if compared to non-lame cows. This higher probability of culling indirectly affects other productivity parameters like reproduction as well (Puerto et al. 2021). The various associations of lameness with other conditions have been demonstrated by (Rittweg et al. 2023): A positive association with other problems like subclinical mastitis or ketosis were detectable.

There is a well-documented impact of lameness on reproduction: Lame cows receive their first insemination later and take longer to be pregnant again (Orgel et al. 2016). It seems that lame cows are only half as likely to conceive after Artificial Insemination (AI) as non-lame cows, with an additional days open of in average 40 days (Hernandez et al. 2001). A negative effect of lameness on reproduction could also been shown for grazing systems (Logroño et al. 2021); here it was shown that lameness diagnosed in early lactation reduced the probability of cows being inseminated and diagnosed pregnant, respectively. This relationship in early lactation was reviewed by (Tsousis et al. 2022): The authors proposed a negative effect of the associated changes in behaviour and stress-level on the hormonal regulation of reproduction and assumed an aggravation of the Negative Energy Balance (NEB); this would effectively lead to reduced cyclicity and hence poorer reproductive performance of lame cows.

The impact of lameness on milk production has been assessed in various studies. Logroño et al. (2021) showed that cows being found lame between calving and their first AI, thus early in pregnancy, produced on average 161 kg of milk less than non-lame herd mates. In a British study (Green et al. 2002) a reduction of 360kg per 305-d lactation of lame cows was found, and (Reader et al. 2011) showed that cows produced between 0.7 and 1.6 kg/d less than non-lame cows; here, it was also shown that cows already showed a significant decrease of milk production up to 8 weeks before lameness was visible and milk production remained 0.42 kg/ d lower, even four weeks after recovery. This points to both the need to detect lameness early as well as the limitations in achieving it. There seems to be an influence of herd and grade of lameness on milk production: Generally, cows in greater parities appear to experience a greater loss of milk production and losses after cows became lame are varying between similarly managed herds (Warnick et al. 2001). It has to be stated that there is an urgent need to identify lame cows early in order to limit the economic impact of lameness (Green et al. 2002).

While the economic impact of lameness is measurable, the detrimental effect it has on animal welfare is difficult to quantify, though obvious. Authors generally agree that lameness is a major animal welfare issue, with potential effect on the public perception of the dairy industry as a whole ((Garvey 2022; Oehm et al. 2019)). Clearly, lameness in dairy cows is a cause for pain and therefore a fundamental welfare concern (Whay und Shearer 2017). Both clinical, i.e., visible and subclinical lameness does contribute to a cow experiencing severe pain, reducing her welfare altogether (Bruijnis et al. 2012). Lame cows show a different behavioural pattern than non-lame herd mates, e.g. less lying time and less time spent eating and show a markedly changed social behaviour. (Galindo und Broom 2002; Weigele et al. 2018; Norring et al. 2014). While this has consequences on productivity itself, these changes in behaviour bear also the potential to be used in automated lameness detection by means of sensors (Beer et al. 2016; Weigele et al. 2018).

***Summary:** Lameness is one of the biggest challenges for the dairy industry as it compromises animal welfare and productivity. Lameness negatively impacts production and other factors, mainly reproduction. Lame cows are at a higher risk of being culled and show marked differences in their behaviour compared to non-lame cows.*

The Occurrence of Lameness

The actual prevalence of lameness in dairy cows is unknown. This apparently surprising fact derives from the difficulty to find a uniform definition and detection of the condition. As Oehm et al. (2019) state after an intensive meta-analysis of the relevant literature, there is an abundance of information, but little solid evidence; from a body of 1941 papers on lameness, the authors were able to extract and use only 53 for a study on risk factors of lameness. Lameness is generally diagnosed by means of visual assessment using scoring systems, which appears to be an unreliable method, moreover, unsystematically used by farmers (Bell et al. 2022; Ghotoorlar et al. 2012; Dutton-Regester et al. 2020). A metanalysis of the current literature (Thomsen et al. 2023a) reports a within-herd range of lameness varying between 0% and 88%; mean prevalence is reported being around 22% and prevalence of severely lame cows (i.e. cows with a score of 4 or 5 on a 5-point-scale) being at 7% in average. Other studies confirm this magnitude: For cows in the UK, an overall lameness prevalence of 29.5% is estimated (Afonso et al. 2020). In a large-scale German study veterinarians assessed the lameness prevalence on dairy farms and found prevalence per farm ranging from 23.1% to 39.1% per farm, depending on the geographical region (Jensen et al. 2022). In this study, farmers however estimated the lameness prevalence considerably lower with 7.1% to 9.5%. The same phenomenon had been reported by (Šárová et al. 2011): In this study on 14 Czech farms, trained observers identified a proportion between 9 and 64% of cows per farm being lame, while the farmers' estimate ranged between 0% and 20%. Apparently, farmers reliably detect very lame cows, but tend to miss cows that are "non-lame" when using a scoring system, i.e., cows that still walk normally but not evenly when using a standard comparison (Beggs et al. 2019).

While the prevalence appears to be around 20% - 30% per farm with significant outliers, the incidence of lameness is largely unknown; in other words: When and why cows become lame is little known. (Lim et al. 2015) observed a total of 731 cows in 4 UK herds in regular time intervals. They identified 1042 "non-lame episodes", of which 50% in the 19-month observation period concerted to "lame". Conversely, of 593 "lame episodes" recorded, 81% (483) returned to "non-lame". Especially regarding the dry period, there is little information. A Canadian study observing the dry period of 455 cows from 9 weeks before calving showed the significance of this time (Daros et al. 2019): The overall incidence rate found was 8.2 new cases of lameness per 100 cows per week, and a cure rate, reverting from lame to non-lame, of 7.1 cases /100 cows /week, leaving a steady rise of lameness prevalence. In total, 50% of cows had developed some form of lameness, while only 31% of them were cured during the dry period.

The transition period is a significant part of the lactation, spanning over late dry period and early lactation and being characterised by negative energy balance (NEB). As reviewed by Tsousis et al. (2022), there is an influence of lameness to this delicate transitional metabolism. The metabolism is likely, however, to have a significant effect on lameness. As reviewed by Bell et al. (2022), the metabolic changes around parturition are also affecting the tissues of the locomotive system, predisposing animals to developing lameness. This is supported by a study covering 4723 calvings and relating the calving ease to the incidence of lameness (Malašauskienė et al. 2022). The fact that animals having experienced some form of dystocia were about twice as likely to develop lameness than cows having calved normally points to a correlation of postpartal-metabolism with the occurrence of lameness. It is not easy to distinguish causes and consequences, but as shown by a clinical study evaluating the metabolism of cows with or without lameness after calving (Zhang et al. 2015), immune system and metabolism are changed in cows being or becoming lame.

As the importance of the transitional metabolism gets clear, the major risk factor for lameness appears to be Body Condition Score (BCS): Various studies show that cows with a low BCS around calving are more prone to develop lameness than normally conditioned cows. The abovementioned study by Green et al. (2014) showed an increased risk for lameness in cows with a BCS <2.5; this finding was confirmed by (Randall et al. 2015). The same for the study by Lim et al. (2015), which showed an increased risk of developing lameness in poorly conditioned cows as well, additionally a decreased risk for recovering from lameness in cows with a BCS <2.5. In an observational study over 9 months, (Kranepuhl et al. 2021) found an increased risk for becoming lame in underconditioned, but also over-conditioned cows. The loss of BCS in the transition period may even serve as a predictor for the risk of developing lameness (Somers et al. 2019).

Summary: *Although lameness is generally seen as a major health problem in dairy cow husbandry, there appears to be uncertainty on its diagnosis and actual occurrence. It seems fair to assume that between 20% to 30% of dairy cows are to a certain extent lame. The information on when cows actually get lame is scarce and the condition is regularly missed. Its occurrence seems to be heavily influenced by the metabolism, especially around calving, with BCS being a major risk factor.*

The Identification of Lameness

As mentioned previously, lameness in dairy cows, though present, is regularly underdiagnosed by farmers and escapes a systematic diagnosis that is beyond the visual scoring systems. Therefore, there appears to be a need for more objective and reliable identification of lameness and, if possible, its prediction. Three ways of achieving this are discernible in literature: identification via a) metabolism; b) behaviour; c) direct assessment.

The metabolism of cows experiencing lameness is detectably changed and the use of "metabolomics", i.e. the "fingerprinting" of metabolites, may point to cows experiencing or being at risk for lameness. The analysis of metabolites in the urine can be used to differentiate lame from non-lame cows (Eckel et al. 2020). In a study observing a total of 120 cows using metabolomic techniques in urine samples, it was possible to differentiate lameness with an accuracy of up to 81% (Randall et al. 2023). These techniques could therefore be used to identify the onset of lameness at an early stage.

The changes of behaviour in lame cows have been mentioned. Changes in mobility, feeding behaviour and social interaction can be taken up by sensor technology and used for lameness identification, possibly at a very early stage (Dutton-Regester et al. 2020). The number and duration of standing and walking, taken up by accelerometers, can identify lameness with a high accuracy of >90% (Beer et al. 2016). Also, the lying behaviour can point to cows experiencing lameness (Weigele et al. 2018). While automated lameness detection is possible and the technology described and available, its information still needs better interpretation and usage studies (Alsaaod et al. 2019)

A direct assessment of lameness is described in different ways: The use of cameras to directly assess the gate of cows is described and available (Anagnostopoulos et al. 2023). This visual assessment shows a high agreement with human visual assessment and may even be more sensitive than the human eye. Another way to directly assess an animal is the use of force-plates, i.e. scales that can measure variations in pressure, allowing for identification of changes in the locomotor system (Ghotoorlar et al. 2012).

***Summary:** An objective detection of lameness in cows is possible in various ways. All technologies appear to require a considerable investment in technology or repeated animal-handling, respectively. The technologies can, to a certain degree, identify animals experiencing lameness at an early stage. There is little information on how to predict lameness before the onset of clinical signs.*

Conclusion: Lameness and what to do about it.

As illustrated, lameness is an ongoing challenge to the dairy industry. One of the most critical aspects appear to be: Lack of uniformity in diagnosis, lack of uniformity in definition, difficulties in correct identification, uncertainty in how to effectively reduce lameness. Various articles are describing strategies to reduce lameness in dairy herds (e.g., Bicalho und Oikonomou 2013; Bell et al. 2022). However, there is still uncertainty on the correct and methodical diagnosis of lameness in cattle. Treatment of acute lameness is possible, e.g., the use of non-steroidal anti-inflammatories has been shown to be efficient in lameness cure and prevention (Wilson et al. 2022). Although routine hoof-rimming is generally accepted as a factor in maintaining locomotive health, some studies actually point to this being a risk factor for developing lameness (Sadiq et al. 2021; Daros et al. 2019). The technology to detect lameness at an early stage is there: Its practical use so far appears to be limited. As lameness seems related to a large extent related to the metabolism of the cow, especially in the transitional period, managing the associated risks appears to be piv9otal in controlling lameness in the first place. Data informing about the problems in this critical phase may aid in assessing the herd's and individuals' risk and correctly identifying the risk factors for lameness.

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