Artykuł przeglądowy *Review*

Relation between clinical lameness and reproductive performance in dairy cows

JAN OLECHNOWICZ, JĘDRZEJ M. JAŚKOWSKI

Department of Veterinary Medicine, Faculty of Animal Breeding and Biology, Poznań University of Life Sciences, Wojska Polskiego 52, 60-625 Poznań, Poland

Olechnowicz J., Jaśkowski J. M.

Relation between clinical lameness and reproductive performance in dairy cows

Summary

Lameness of cows is an important factor influencing the longevity and performance of the herd, including milk yield losses. It has a negative impact on reproductive performance and constitutes an increasing risk for early culling. Claw disorders, such as white line diseases, sole ulcers or papillomatous digital dermatitis, are the most frequent causes of clinical lameness in dairy cows. Lameness most often appears within 100 days postpartum, and its incidence was calculated at 54.5 to 65% per 100 cows, whereas the mean prevalence of lameness has been estimated at 20.6%. Lame cows exhibit different oestrus behavior than non-lame cows. Above all, lame cows had a shorter oestrus, and an increased locomotion score was associated with a shorter time of standing and walking as a consequence of a longer time of lying down. A poor oestrus detection rate is likely to be a more important factor in reducing average fertility levels. Hence, the average conception rate and pregnancy rate for lame cows are lower, and the rates of services per conception are higher. Lame cows have a longer interval from calving to conception compared with non-lame cows. In the case of lame cows with lesions and multiple lesions this interval amounted to 140 and 170 days, respectively, as compared with 100 days for healthy cows. Ovarian cysts are observed in about 10-30% of lactating dairy cows and are more likely to occur within the first 80 days postpartum, i.e. during the same period when hoof disorders and lameness occur. Lameness in cows within the first 30 days postpartum was associated with a higher incidence of ovarian cysts, a lower likelihood of pregnancy and lower fertility than in non-lame cows. The effect of lameness on culling within the first 60 DIM was lower, but cows diagnosed in this period seemed to be at a greater risk of being culled between 121 and 240 DIM. Nevertheless, when deciding whether to cull a cow, one should consider such factors as parity, lactation stage, milk yield, reproductive performance, health, season and animal welfare.

Keywords: cow, clinical lameness, oestrus behavior, ovarian cyst, fertility, culling

The prevention of lameness in first calving heifers could be important both from the economic point of view and for animal welfare (21). Claw disorders cause approximately 90% of lameness in dairy cows (32). However, 90% of lesions in lame cows were related to white line diseases, sole ulcer, solar abscess and double sole. In many European countries and the USA, papillomatous digital dermatitis (PDD) constitutes a significant problem in many dairy herds (37, 38, 50). The prevalence of sole ulcers and white line diseases was significantly associated with digital cushion thickness (DCT); cows with a low DCT were at a higher risk of claw horn lesions (1, 2). Several factors such as breed, housing system and the purchase of heifers are strongly associated with an increased likelihood of PDD in cows (38). Hence, dairy managers should consider their biosecurity programs and control „cow hoof" plans (50). Cows kept in a pasture system at the end of lactation will have less severe hoof disorders and a reduced likelihood of clinical lameness compared to similar cows in a housed system (33). Lameness is an important factor influencing the longevity of cows because of its high prevalence as well as its fundamental and extensive effects on the performance of the herd, resulting in significant production losses, its negative impact on reproductive performance and an increased risk for early culling (3, 6, 7, 9, 18, 19, 23, 30). Lame cows in the first lactation are more likely to develop lameness in subsequent lactations (21). It can be an effect of pathological changes in the horn of claws from the first lactation or factors that predispose cows to lameness (e.g. hoof conformation). Others report that lying comfort as well as the comfort of the stalls, the time that cows spend away from their pen during milking, hoof trimming frequency, and concrete floor are also strongly associated with lameness in dairy cows (9, 11). Feeding cows with

a diet containing 30g/d of a *Saccharomyces cerevisiae* culture from the 20th until the 140th day postpartum during months of heat stress did not affect the incidence of lameness but tended to reduce the lameness score (4). Pain caused by hoof diseases is a source of stress for cows, which influences reproductive hormone release in the follicular phase (10). A consequence of stress is a reduced frequency and amplitude of gonadotropin-releasing hormone (GnRH) and lutein hormone (LH) pulses. The reduction in endogenous GnRH/LH secretion ultimately deprives the ovarian follicle of adequate gonadotropin supply, leading to reduced oestradiol production by follicles growing more slowly (10). Hence the negative impact of stress on the function of ovaries. For the evaluation of locomotion scoring of dairy cows, the locomotion scoring system suggested by Spreacher et al. (44) has been applied. According to these authors cows with scores of 3 or more are clinically lame.

The objective of this study was to present on the basis of literature data the occurrence of lameness in cows postpartum and its impact on oestrus behavior, days open from calving to conception, as well as on fertility and culling.

The incidence and prevalence of lameness in cows postpartum

Approximately 20% of intensely managed dairy cows worldwide are lame at any one time (5, 12). The mean annual incidence of lameness is 54.5 new cases per 100 cows within the range of 10.7 to 170.1, and the mean values during summer and winter are 22.9 and 31.7, respectively. The prevalence of lameness is defined as the proportion of cows with scores of 3 or more for each visit in the herd. The mean annual prevalence was 20.6% within the range of 2.0 to 53.9% for the 37 farms analyzed in the study (5).

The incidence of lameness within 30 days postpartum was 2.2% (30). Other sources reported an incidence between 3.5 and 6% during the first 30 days of lactation (6, 29). According to Collik et al. (6), a high percentage of lame cows (65%) occurred during the first 100 days postpartum. These authors reported that the incidence of digital dermatitis (DD) and interdigital dermatitis (IDD) was reduced as lactation progressed; however, sole ulcers persisted during the first 150 days postpartum. Indeed, lameness is more likely to occur during the first 60 days postpartum (22). Cows diagnosed with clinical lameness during the first 70 days in milk (DIM) were 25% less likely to become pregnant as compared with non-lame cows (2). The most important risk factors for claw horn diseases include parturition and critical changes occurring during the transition period (21 days before and after calving) and those related to new environmental conditions, such as the type of floor surfaces, type of housing and nutrition (6, 16, 30, 44).

The prevalence of lameness, detected by visual locomotion scoring (VLS $\geq$ 3), for five farms was 26.5, 54.2, 33.9, 51.8, and 39.3% (2). The averaged prevalence of lameness evaluated by a similar method by Espejo and Endres (11) was 24.6% within the range of 3.3 to 57.3%.

The influence of lameness on ovarian cyst formation and follicular growth

Cystic ovarian diseases are some of the most frequently diagnosed reproductive performance disorders in dairy cows. The formation and development of ovarian cysts is not fully understood (28). Ovarian cysts are more likely to occur within the first 80 days postpartum and affect about 10-30% lactating dairy cows (12). These diseases have been associated with risk factors such as genetic predisposition, early postpartum period, nutritional status, calving season, the level of milk production and cow management (12, 28, 30). Lactation rank was not a risk factor for early cyst development (12). Ovarian cysts are a risk factor for infertility in dairy cows (12, 15, 28, 30). Lameness in cows within the first 30 days postpartum was associated with a higher incidence of ovarian cysts, a lower likelihood of pregnancy, and lower fertility than in non-lame cows (30). Cows, which were lame within 30 days postpartum were 2.63 times more likely to develop an ovarian cyst before the first mating as compared with healthy cows.

Cows with ovarian cysts had a longer period from calving to the first service (by approximately 15 days), and this time was the period in which ovarian activity was to be resumed. Similarly, other researchers reported that ovarian cysts were also associated with increases in median days open of 28 days (26). They also observed negative effects of *mastitis*, cystic ovarian disease, lameness, and *metritis* on pregnancy risk, which increased as the interval between the last disease episode and insemination decreased (27). Results presented by Garbarino et al. (12) support the hypothesis that lameness has a detrimental effect on ovarian activity in Holstein cows in the early postpartum period. The median interval between calving and the first luteal phase was 36 days for lame cows, 32 days for moderately lame cows and 29 days for non-lame cows. In high-yielding Holstein cows in the postpartum period, based on milk progesterone profiles, only 42.9% had normal ovarian cycles, whereas 57.1% had abnormal ovarian cycles (39). Abnormal ovarian cycles included a prolonged luteal phase, anovulation, a short luteal phase and the cessation of cyclicity. A prolonged luteal phase and anovulation are very important abnormal ovarian cycles, and both reduce reproductive performance, including rates of conception and the pregnancy rate within 100 days after calving. However, according to other researchers, ovarian cysts and lameness were recorded throughout lactation (20). The occurrence of ovarian cysts was associated with uterine infection (15). Cows with *endometritis* had ovarian cysts significantly more often. Also high milk production was positively correlated with the development of ovarian cysts. Ac-

cording to these authors, ovarian cyst diagnosed after the puerperium had a negative effect on fertility, whereas ovarian cyst diagnosed during the puerperium did not affect reproduction. Morris et al. (31) investigated the effect of somatic cell count (SCC), body condition score (BCS) and lameness score on follicular growth and ovulation in dairy cows for 30 to 80 days postpartum. Finally, lameness reduced the proportion of cows that ovulated, and a synergistic effect of high SCC and lameness further reduced that proportion. However, follicular growth and maximum diameter were unaffected by high SCC, low BCS or lameness.

The general and sexual behaviour of cows in relation to lameness

The pain and discomfort caused by claw diseases in cows negatively influence animal welfare and reduce their productivity. Hence, differences are observed in the behaviour of lame and healthy cows, not only in the oestrus period, but also on the pasture and when returning to the barn. Such observations showed that lame cows entered the milking parlour later than healthy cows, were more restless in the parlour, lay down longer, grazed for a shorter time, taking smaller rations of fodder, and spent a greater proportion of time ruminating (17, 48). As a consequence, lame cows produce less milk or lose weight and have less distinct oestrus manifestations. Lameness as a common disease in dairy cows negatively affects their fertility. The duration of oestrus was similar in both lame and non-lame cows, and averaged 17.2 and 18.7 h, respectively (43). However, the proportion of cows with a shorter oestrus (8.5-13 h) was greater among lame than non-lame animals (29.7% and 17.6%, respectively). In both groups of cows the duration of oestrus was positively correlated with the total oestrus behaviour score, with correlation coefficients of $r = 0.5$ for non-lame cows and $r = 0.3$ for the lame ones. Such results were recorded in the case of a loose housing system in tropical India. However, in the methodology accepted by the authors of this study (with four observations of 30 min a day) (45), an oestrus detection rate of approximately 84% can be achieved. Other researchers report that a detection rate of approx. 70% can be achieved with two or three 30-minute observation periods a day (46). Lame cows have a shorter period of standing and walking as a consequence of a longer time of lying down, and they exhibit reduced sexual behaviour (47). Similarly, an increased locomotion score was associated with increases in the percentage of cows lying down and their return time from the milking parlor (24). The expression of oestrus in cows was observed according to the methods of van Eerdenburg et al. (45), with thresholds of 50 points (14). The results of the study by these authors indicate that there is no correlation between mild or subclinical lameness and the intensity of oestrus expression when this evaluation system is applied (14). The behaviour of dairy cows can also be influenced by the environment, especially by poor stall designs with obstructions which cause behavioural changes in oestrus cows and prolong milking times and management tasks (7). Straw yards are better than cubicles in encouraging cows to lie down and in providing a soft and dry surface for standing. Thus straw yards can be helpful in the prevention of lameness (40). Oestrus behavior may be impaired due to lameness (29). The reproductive biology of contemporary high-yielding cows differs from that of their ancestors and from that of yearling heifers (49). These cows tend to have shorter oestrus cycles, fewer standing events and a higher rate of multiple ovulation.

The effect of lameness on the calving-to-conception interval in cows

During the time from calving to conception, 50 out of 421 (12%) cows were removed from the herd within 200 days after calving (19). Such disorders as dystocia, retained placenta and *metritis* were not significantly associated with the time from calving to conception. Lame cows with claw lesions and cows with multiple lesions were 0.52 and 0.31 times less likely to conceive than healthy cows, respectively. In healthy cows the interval from calving to conception was 100 days, whereas in lame cows with lesions and multiple lesions this interval was longer and amounted to 140 and 170 days, respectively. The calving to conception interval as well as the number of services per conception increased in lame cows. Results reported by other researchers showed a significant relation between an increasing degree of lameness and time to conception (18). Cows classified as non-lame became pregnant sooner than cows classified as moderately lame or lame. Additionally, among cows classified as lame, cows with low cumulative locomotion scores became pregnant sooner than those with medium or high scores. The number of weeks of lameness increased from 1, to 2 to 5 in cows with low, medium and high scores, respectively. The number of lame cows that were removed from the herd during lactation increased from 18% to 25% to 40% in cows with low, medium and high scores, respectively. Other authors also pointed to the fact that clinically lame cows had longer intervals from calving to the first service and to conception (6, 30). The conception rate declined in cows treated for lameness within 63 d of mating (31). Similarly, a significant increase in days from calving to conception was observed for cows diagnosed as lame as compared with those considered non-lame during the first 70 days in milk (DIM) (2).

A comparison of the fertility of 123 lactating cows which had sole or white line lesions with 584 lactations of cows without these lesions showed significant differences in calving to first service and calving to conception intervals when adjusted for herd, lactation rank, year and month of calving (29). Cows with these lesions showed an average increase of seven days in the calving to first service interval, and an average increase of 11 days in the calving to conception interval. The in-

crease in these intervals was very prominent for cows, in which sole or white line diseases occurred between 36 and 70 days after calving. All diseases (retained placenta, non-systemic *metritis*, systemic *metritis*, ovarian cysts and lameness) were associated with an increase in median days open; however, lameness and ovarian cysts were clearly associated with increases of 28 and 22 d, respectively (26).

The effect of lameness on fertility

The infertility of cows has often been linked to a rising milk yield in high-producing dairy cattle (11, 39). However, in some studies no association was found between high milk production and reduced fertility (13). Moreover, highly fertile cows, defined as those becoming pregnant within 90 days postpartum, produced the most milk on day 50 postpartum. In high-producing dairy herds, an improvement of management practices should be one of the main factors influencing fertility. Several studies have also shown that lameness has a negative effect on fertility in dairy cows (12, 19, 23, 44). It has been reported that cows diagnosed with clinical lameness during the first 70 DIM were 25% less likely to become pregnant than non-lame cows (2). Similarly, lameness in dairy cows within the first 60 days postpartum was associated with decreased fertility as well as lower serum concentrations of P, Zn and vitamin E (25). A poor oestrus detection rate is likely to be a more important factor in reducing average fertility levels (29). The proportion of cows with above-average fertility was lower for lame cows (from 36 to 47%, depending on the type of hoof disease) than for healthy cows (53%). Similarly, the average conception rate was lower in lame cows (31%) than in non-lame cows (40%) (29). In control cows compared with lame cows, pregnancy rate to first service was higher (56.3 and 45.9%, respectively) and services per conception rate was lower (1.72 and 2.14, respectively) (6). Reproductive disorders and lameness were significantly associated with body condition loss during the antenatal period (22). For further health and fertility, it seems to be advantageous, when cows are dried off in moderate body condition. Other researchers reported that body condition scores (BCS) were also positively associated with DCT (1).The following hoof diseases were mainly associated with poorer reproductive performance: sole ulcers (23, 42), hell-horn erosions, sole hemorrhages and ulcers, and white line fissures (42). Cows diagnosed with these lesions also tended to have an increased occurrence of *mastitis*, teat injuries, milk fever and more hormonal treatments.

Early endocrine measurements of dairy cows fertility better characterized their fertility in comparison with traditional methods. On the basis of progesterone profiles for 1106 lactations and 30,145 progesterone samples, the interval from calving to the commencement of luteal activity (CLA), the proportion of luteal activity during the first 60 days after calving (PLA) and the interval from calving to the first ovulatory oestrus (OOE) were determined (35). Many of the environmental factors analyzed had the largest effect on early measurements. Parity and lameness had the largest effect on CLA, OOE and PLA. *Mastitis*, housing and the season of calving were also found to have a substantial effect on early measurements, but the influence of the level of milk production was less significant. Only housing and the incidence of lameness affected late fertility measurements (35). In lame cows, defined as those assigned at least once a visual locomotion score (VLS) of 3 or more, the hazard ratio of being detected pregnant was 0.85 (VLS $\geq$ 3) or 0.76 (VLS $\geq$ 4) as compared with non-lame cows (2). In order to improve cows' fertility, it is also possible to apply direct genetic selection, using traits such as daughter pregnancy rate, longevity or body condition score (49).

The relationship between lameness and culling

The effect of lameness on culling seemed to depend on the time when lameness was diagnosed and the time of culling (3, 8). The effect of lameness on culling within the first 60 DIM was low. However, cows diagnosed in this period seemed to be at a greater risk of being culled between 121 and 240 DIM. Basically, lameness was associated with a short-term increase in the culling rate between 61 and 120 DIM, but also toward the end of lactation (3). However, the greatest effect of lameness on culling was observed during mid- to late lactation. A decreasing influence of lameness on culling was observed during late lactation (> 240 DIM), perhaps as an effect of reduced milk yield, but the pregnancy status of cows plays a more important role in culling decisions in this period (3, 36). It was shown that the effect of lameness (and other diseases) on the decision to cull varies across lactation and must be analyzed in a time-dependent manner (3). Clinical lameness was associated with an increased hazard of culling/death. This ratio was 1.45 (VLS $\geq$ 3) or 1.74 (VLS $\geq$ 4) for lame cows as compared with non-lame cows (2). In general, the earlier it was known that a cow was pregnant, the smaller the risk of culling was (36). According to a literature review, in herds of dairy cows the rate of culling due to lameness is difficult to calculate, but in some studies this percentage was estimated at 15.7% to 19.9% (6, 8). Infectious foot lesions did not have a significant effect on culling, whereas hoof horn lesions were associated with an increased culling risk (8). Authors of several studies showed that many other factors also influence the decision on whether to cull a cow (34, 36, 41). These include parity, lactation stage, milk yield, reproductive performance, health, season and animal welfare.

Recapitulation

The main causes of lameness in dairy cows are hoof diseases, such as papillomatous digital dermatitis, sole ulcers and white line diseases. These diseases occur

during the first 100 days postpartum, and their incidence is estimated at 54.5 to 65%, whereas the mean prevalence of lameness is evaluated at 20.6%. Lame cows are characterised by a shorter oestrus, a shorter time of standing and walking as a consequence of a longer time of lying down, and a reduced expression of sexual behavior. A poor oestrus detection rate is likely to be a more important factor in reduced average fertility levels. Clinically lame cows have longer intervals from calving to the first service and to conception. Additionally, ovarian cysts are more likely to occur within the first 80 days postpartum. Lameness in cows is associated with a higher incidence of ovarian cysts. Finally, the earlier it is known that a cow is pregnant, the lower the risk of culling is.

References

1. *Bicalho R. C., Machado V. S., Caixeta L. S.*: Lameness in dairy cattle: a debilitating disease or a disease of debilitated cattle? A cross-sectional study of lameness prevalence and thickness of digital cushion. J. Dairy Sci. 2009, 92, 3175-3184.
2. *Bicalho R. C., Vokey F., Erb H. N., Guard C. L.*: Visual locomotion scoring in the first seventy days in milk: impact on pregnancy and survival. J. Dairy Sci. 2007, 90, 4586-4591.
3. *Booth C. J., Warnick L. D., Gröhn Y. T., Maizon D. O.*: Effect of lameness on culling in dairy cows. J. Dairy Sci. 2004, 87, 4115-4122.
4. *Bruno R. G. S., Rutigliano H., Cerri R. L., Robinson P. H., Santos J. E. P.*: Effect of feeding yeast culture on reproduction and lameness in dairy cows under heat stress. Anim. Reprod. Sci. 2009, 113, 11-21.
5. *Clarkson M. J., Downham D. Y., Faull W. B., Hughes J. W., Manson F. J., Merritt J. B., Murray R. D., Rusell W. B., Sutherst J. E., Ward W. R.*: Incidence and prevalence of lameness in dairy cattle. Vet. Rec. 1996, 138, 563-567.
6. *Collik D. W., Ward W. R., Dobson H.*: Associations between types of lameness and fertility. Vet. Rec. 1989, 125, 103-106.
7. *Cook N. B., Nordlund K. V.*: The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. Vet. J. 2009, 179, 360-369.
8. *Cramer G., Lissemore K. D., Guard C. L., Leslie K. E., Kelton D. F.*: The association between foot lesions and culling risk in Ontario Holstein cows. J. Dairy Sci. 2009, 92, 2572-2579.
9. *Dippel S., Dolezal M., Brenninkmeyer C., Brinkmann J., March S., Knierim U., Winckler C.*: Risk factors for lameness in freestall-housed dairy cows across two breeds, farming systems, and countries. J. Dairy Sci. 2009, 92, 5476-5486.
10. *Dobson H., Smith R. F.*: What is stress, and how does it affect reproduction? Anim. Reprod. Sci. 2000, 60-61, 743-752.
11. *Espejo L. A., Endres M. I.*: Herd-level risk factors for lameness in high-producing Holstein cows housed in freestall barns. J. Dairy Sci. 2007, 90, 306-314.
12. *Garbarino E. J., Hernandez J. A., Shearer J. K., Risco C. A., Thatcher W. W.*: Effect of lameness on ovarian activity in postpartum Holstein cows. J. Dairy Sci. 2004, 87, 4123-4131.
13. *García-Ispierto I., López-Gatius F., Santolaria P., Yániz J. L., Nogareda C., López-Béjar M.*: Factors affecting the fertility of high producing dairy herds in northeastern Spain. Theriogenology 2007, 67, 632-638.
14. *Gómez F., de Boer H., van Eerdenburg F. J. C. M.*: Relationship between mild lameness and expression of oestrus in dairy cattle. Vet. Rec. 2003, 152, 403-404.
15. *Gossen N., Hoedemaker M.*: Reproductive performance of dairy cows with relation to time of ovarian cyst formation. Bull. Vet. Inst. Pulawy 2006, 50, 159-161.
16. *Gröhn Y. T., Rajala-Schultz P. J., Allore H. G., DeLorenzo M. A., Hertl J. A., Galligan D. T.*: Optimizing replacement of dairy cows: modeling the effects of diseases. Prev. Vet. Med. 2003, 61, 27-43.
17. *Hassall S. A., Ward W. R., Murray R. D.*: Effects of lameness on the behaviour of cows during the summer. Vet. Rec. 1993, 132, 578-580.
18. *Hernandez J. A., Garbarino E. J., Shearer J. K., Risco C. A., Thatcher W. W.*: Comparison of the calving-to-conception interval in dairy cows with different degrees of lameness during the prebreeding postpartum period. J. Am. Vet. Med. Assoc. 2005, 227, 1284-1291.
19. *Hernandez J. A., Shearer J. K., Webb D. W.*: Effect of lameness on the calving--to-conception interval in dairy cows. J. Am. Vet. Med. Assoc. 2001, 218, 1611--1614.
20. *Heuer C., Schukken Y. H., Dobbelaar P.*: Postpartum body condition score and results from the first test day milk as predictors of disease, fertility, yield, and culling in commercial dairy herds. J. Dairy Sci. 1999, 82, 295-304.
21. *Hirst W. M., Murray R. D., Ward W. R., French N. P.*: A mixed effects time-to--event analysis of the relationship between first-lactation lameness and subsequent lameness in dairy cows in the UK. Prev. Vet. Med. 2002, 54, 191-201.
22. *Hoedemaker M., Prange D., Gundelach Y.*: Body condition change ante- and postpartum, health and reproductive performance in German Holstein cows. Reprod. Dom. Anim. 2009, 44, 167-173.
23. *Hultgren J., Manske T., Bergsten Ch.*: Associations of sole ulcer at claw trimming with reproductive performance, udder health, milk yield, and culling in Swedish dairy cattle. Prev. Vet. Med. 2004, 62, 233-251.
24. *Juarez S. T., Robinson P. H., DePeters E. J., Price E. O.*: Impact of lameness on behavior and productivity of lactating Holstein cows. Appl. Anim. Behav. Sci. 2003, 83, 1-14.
25. *Kiliç N., Ceylan A., Serin İ., Gökbulut C.*: Possible interaction between lameness, fertility, some minerals, and vitamin E in dairy cows. Bull. Vet. Inst. Pulawy 2007, 51, 425-429.
26. *Lee L. A., Ferguson J. D., Galligan D. T.*: Effect of disease on days open assessed by survival analysis. J. Dairy Sci. 1989, 72, 1020-1026.
27. *Loeffler S. H., de Vries M. J., Schukken Y. H.*: The effects of time of disease occurrence, milk yield, and body condition on fertility of dairy cows. J. Dairy Sci. 1999, 82, 2589-2604.
28. *López-Gatius F., Santolaria P., Yániz J., Fenech M., López-Béjar M.*: Risk factors for postpartum ovarian cysts and their spontaneous recovery or persistence in lactating dairy cows. Theriogenology 2002, 58, 1623-1632.
29. *Lucey S., Rowlands G. J., Russell A. M.*: The associations between lameness and fertility in dairy cows. Vet. Rec. 1986, 118, 628-631.
30. *Melendez P., Bartolome J., Archbald L. F., Donovan A.*: The association between lameness, ovarian cysts and fertility in lactating dairy cows. Theriogenology 2003, 59, 927-937.
31. *Morris M. J., Walker S. L., Jones D. N., Routly J. E., Smith R. F., Dobson S. H.*: Influence of somatic cell count, body condition and lameness on follicular growth and ovulation in dairy cows. Theriogenology 2009, 71, 801-806.
32. *Murray R. D., Downham D. Y., Clarkson M. J., Faull W. B., Hughes J. W., Manson F. J., Meritt J. B., Russel W. B., Sutherst J. E., Ward W. R.*: Epidemiology of lameness in dairy cattle: description and analysis of foot lesions. Vet. Rec. 1996, 138, 586-591.
33. *Olmos G., Boyle L., Hanlon A., Patton J., Murphy J. J., Mee J. F.*: Hoof disorders, locomotion ability and lying times of cubicle-housed compared to pasture-based dairy cows. Livest. Sci. 2009, 125, 199-207.
34. *Pérez-Cabal M. A., Garcia C., González-Recio O., Alenda R.*: Genetic and phenotypic relationships among locomotion type traits, profit, production, longevity, and fertility in Spanish dairy cows. J. Dairy Sci. 2006, 89, 1776-1783.
35. *Petersson K. J., Strandberg E., Gustafsson H., Berglund B.*: Environmental effects on progesterone profile measures of dairy cow fertility. Anim. Reprod. Sci. 2006, 91, 201-214.
36. *Rajala-Schultz P. J., Gröhn Y. T.*: Culling of dairy cows. Part II. Effects of diseases and reproductive performance on culling in Finnish Ayrshire cows. Prev. Vet. Med. 1999, 41, 279-294.
37. *Read D. H., Walker R. L.*: Papillomatous digital dermatitis (footwarts) in California dairy cattle: clinical and gross pathologic findings. J. Vet. Diagn. Invest. 1998, 10, 67-76.
38. *Rodriguez-Lainz A., Melendez-Retamal P., Hird D. W., Read D. H., Walker R. L.*: Farm- and host-level risk factors for papillomatous digital dermatitis in Chilean dairy cattle. Prev. Vet. Med. 1999, 42, 87-97.
39. *Shrestha H. K., Nakao T., Suzuki T., Higaki T., Akita M.*: Effects of abnormal ovarian cycles during pre-service period postpartum on subsequent reproductive performance of high-producing Holstein cows. Theriogenology 2004, 61, 1559--1571.
40. *Singh S. S., Ward W. R., Hughes J. W., Lautenbach K., Murray R. D.*: Behaviour of dairy cows in straw yard in relation to lameness. Vet. Rec. 1994, 135, 251--253.
41. *Sogstad Å. M., Østerås O., Fjeldaas T., Nafstad O.*: Bovine claw and limb disorders related to culling and carcass characteristics. Livest. Sci. 2007, 106, 87-95.
42. *Sogstad Å. M., Østerås O., Fjeldaas T.*: Bovine claw and limb disorders related to reproductive performance and production diseases. J. Dairy Sci. 2006, 89, 2519-2528.
43. *Sood P., Nanda A. S.*: Effect of lameness on estrous behavior in crossbred cows. Theriogenology 2006, 66, 1375-1380.
44. *Spreacher D. J., Hostetler D. E., Kaneene J. B.*: A lameness scoring system that uses posture and gait to predict dairy cattle reproductive performance. Theriogenology 1997, 47, 1179-1187.
45. *Van Eerdenburg F. J. C. M., Loeffler H. S. H., Van Vliet J. H.*: Detection of oestrus in dairy cows: a new approach to an old problem. Vet Q. 1996, 18, 52-54.
46. *Van Vliet J. H., Van Eerdenburg F. J. C. M.*: Sexual activities and oestrus detection in lactating Holstein cows. Appl. Anim. Behav. Sci. 1996, 50, 57-69.
47. *Walker S. L., Smith R. F., Jones D. N., Routly J. E., Dobson H.*: Chronic stress, hormone profiles and estrus intensity in dairy cattle. Horm. Behav. 2008, 53, 493-501.
48. *Walker S. L., Smith R. F., Routly J. E., Jones D. N., Morris M. J., Dobson H.*: Lameness, activity time-budgets, and estrus expression in dairy cattle. J. Dairy Sci. 2008, 91, 4552-4559.
49. *Weigel K. A.*: Prospects for improving reproductive performance through genetic selection. Anim. Reprod. Sci. 2006, 96, 323-330.
50. *Wells S. J., Garber L. P., Wagner B. A.*: Papillomatous digital dermatitis and associated risk factors in US dairy herds. Prev. Vet. Med. 1999, 38, 11-24.

Author's address: dr hab. Jan Olechnowicz, Osiedle Wichrowe Wzgórze 13/93, 61-675 Poznań