Detection of digital and interdigital dermatitis in Holstein Friesian dairy cows by means of infrared thermography

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SUMMARY

Diseases of the bovine foot are a serious threat to dairy cows welfare and productivity. Commonly divided in infectious and non-infectious depending on their aetiology, infectious lesions include digital dermatitis, interdigital dermatitis, heel horn erosion, and foot rot, whereas the most common non-infectious lesions are sole ulcer, toe ulcer, sole haemorrhage, and white line disease. Infrared thermography (IRT) has been adopted in livestock studies for different analyses such as metabolic responses to thermal stress and the diagnosis of inflammatory processes. The aim of this study was to evaluate the potential usefulness of infrared thermography as a non-invasive tool to rapidly screen digital and interdigital dermatitis (DD and ID) in dairy cows. Forty-eight healthy cows and forty-eight cows affected by DD and ID on central and interdigital regions of the hind feet were enrolled. Feet were cleansed to reduce biases and artifacts and left to dry for five minutes to restore normal blood flow. Thermography images of the hind feet were then collected using a digital infrared camera. Foot temperature was measured in four regions: central area of the hind foot (R1), interdigital area of the hind foot (R2), lateral (R3) and medial (R4) claw in the hind foot. Higher temperature values were found in the central (R1) and interdigital area (R2) compared to lateral (R3) and medial (R4) areas in both healthy and diseased cows ($P<0.001$). Moreover, cows affected by DD and ID showed higher foot temperature values compared to healthy cows in the R1 and R2 regions ($P<0.001$). Results from the present study show that IRT could be a useful diagnostic tool for the detection of DD and ID in dairy cows. The obtained results suggest that IRT could contribute in defining the localization of areas of increased inflammation and could be useful for veterinary podologists, permitting to act directly on the lesion detected by thermography rather than on the whole foot.

KEY WORDS

Dairy cows; digital dermatitis; foot temperature; infrared thermography; interdigital dermatitis.

INTRODUCTION

Lameness represents one of the main causes of decreased productive performance and impaired animal welfare in the dairy industry. Foot lesions are commonly categorized according to their aetiology into infectious and non-infectious lesions[1,2]. Infectious lesions include digital dermatitis, interdigital dermatitis, heel horn erosion, and foot rot, whereas the most common non-infectious lesions are sole ulcer, toe ulcer, sole haemorrhage, and white line disease. Digital and interdigital dermatitis are a dynamic and multifactorial infectious foot disease with increasing prevalence in many countries[3,4].
The precise aetiology of digital and interdigital dermatitis is unknown. The marked susceptibility of lesions to topical antibiotics[5], as well as the isolation of spirochetes and proteobacteria from the lesions caused by digital and interdigital dermatitis, respectively suggest that bacteria have an important role in the development of these diseases[6].
Early detection of digital and interdigital dermatitis is the first step towards therapeutic resolution and reduction of reservoirs of infection within the herd[7,8]. Therefore, the need to make a rapid and simple diagnosis remains a key feature in treating and controlling lameness in dairy cows. Traditionally, locomotion scoring is used to identify developing diseases of limb and foot or for clinical follow-up. This approach, besides being time-consuming to be used on the whole herd, may not always be suitably sensitive to identify foot lesions[9]. Moreover, dermatitis is often present without any sign of locomotion impairment, and lameness does not appear until the lesion becomes severe[10].
Infrared thermography (IRT) has been adopted in animal production studies for different analyses such as metabolic responses to thermal stress[11] and the diagnosis of inflammatory processes[12,13].
The use of IRT to recognize lameness in cattle has increased largely in the last years since it represents a non-invasive method, ease of automation and low cost[14]. The newest generation of IRT cameras is capable of measuring temperature in real-time.

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The equipment is light, portable and temperature detection shows great sensitivity, which is significant in recording the heat generated by animals' skin[15]. Additionally, the camera software permits analysis of temperature data in every surface or area of the thermogram. Therefore, IRT can be useful to detect thermal abnormalities in animals by characterizing changes in their skin temperature[16].

The skin surface is a highly efficient radiator, a fact that permits to detect infrared emissions of the skin and to map temperature distributions in a non-invasive manner[17]. IRT permits to detect even small changes in temperature with precision and without the need for physical contact with the animals[18], and has therefore become important as a safe assessment method in experiments.

Aim of this study was to evaluate the potential usefulness of infrared thermography as a non-invasive tool to rapidly screen digital and interdigital dermatitis in dairy cows.

MATERIALS AND METHODS

Farm and animal selection

The study was conducted in an intensive Italian dairy herd located in North Italy (45° 38' N; 10° 87' E) at an altitude of 68 m. The selected farm had 200 Holstein Friesian dairy cows in lactation. The herd production was in an average of 8412±1426 kg of milk per cow in 310±11 days. Farms made a dry period of 55 days and a period of steaming-up of 15 days before calving. Cows were on a maintenance claw-trimming scheme before the study, thus receiving routine hoof trimming twice a year in the farm (-70±15 days before and +50±15 days after calving). Scheduled hoof trimming sessions were performed by a veterinarian professional claw trimmer.

Forty-eight healthy cows (35±10 months; mean body weight 630±74 kg) and forty-eight cows affected by foot diseases (39±11 months; mean body weight 626±95 kg) were enrolled in the study.

All cows were placed in an up-right chute equipped with a headlock gate and a manually operated rope foot lift at 55±10 days in milk. Each limb was raised with a rope fastened on the mid-diaphysis of the third metatarsal bone. All feet were cleansed and trimmed to remove stained, overgrown hoof horn tissue following guidelines of the Dutch Technique[19]. During trimming sessions, one leg at a time was raised to preserve as much as possible animals' welfare and reduce their stress. A complete clinical examination was performed based on the cow's reaction to palpation. The disease status of the foot was confirmed using a thorough clinical examination. In the cases where both hind feet were compromised, the one with higher clinical relevance was selected based on the reaction to palpation and pain. Moreover, all lame cows were also checked and recorded. The same procedure was performed also for healthy cows.

Hind feet of enrolled animals were cleaned with cold water to remove dirt and left to dry. Sick cows were affected by digital dermatitis (DD) and interdigital dermatitis (ID), with DD and ID lesions localized in central and interdigital regions of the hind foot. Selected cows were separated from the herd and introduced in a crush where the affected foot was nursed.

Protocols of animal husbandry and experimentation were reviewed and approved in accordance with the standards recommended by the Guide for the Care and Use of Laboratory Animals and Directive 2010/63/EU for animal experiments.

Infrared thermography and thermogram analysis

Thermography images of hind feet were collected from each animal using a digital infrared camera (ThermaCam P25 Model, Flir Systems, Boston, MA, USA). All feet were cleaned and trimmed to remove dirt before the acquisition of thermal images to reduce biases and artifacts. After washing and drying of the feet, a five-minute timeout period was set to allow blood flow to return to its pre-wash state. All thermographic imaging was performed in a closed, indoor environment, while the animals were restrained in the stall in a standing position.

Mean ambient temperature was recorded at the IRT time points and it showed a mean value of 15.7±3.61 °C.

All images were scanned at the same distance (0.7 m) from the subject to reduce the effects of environmental factors on thermographic readings. The settings of the camera were as follows: temperature range: 10-40 °C; emissivity of skin: 0.98; reflected air temperature (Trifl): 20 °C; distance between the camera and skin surface (Dist): 0.7 m; and view field (FOV): 23°. The detector consisted of a focal plane array (FPA) uncooled microbolometer with the following specifications: 320 × 240 pixels resolution, thermal sensitivity of 0.08 °C (at 30 °C), spatial resolution (IFOV) of 1.3 mrad, spectral range between 7.5 and 13 m accuracy ±2 °C. Automatic corrections based on user input were conducted for reflected ambient temperature, distance, relative humidity, and atmospheric transmission.

Foot temperature was measured in four specific regions of interest: central area of the hind foot (R1), interdigital area of the hind foot (R2), lateral (R3) and medial (R4) claw in the hind foot. The absolute mean temperature of each region of interest was calculated using thermography software (Thermacam Researcher Basic 2.8 software, FLIR, Wilsonville, Oregon, USA).

Statistical analysis

All data were tested for normality of distribution using Kolmogorov-Smirnov test. All data were normally distributed ($P>0.05$) and statistical analysis was performed. Two-way analysis of variance (ANOVA) was applied to evaluate the significant change of temperature among the selected foot areas and whether significant differences in foot temperatures occur between healthy cows and cows affected by foot diseases. When significant differences were found Bonferroni's post hoc comparison was applied. The statistical analysis was performed using the STATISTICA software package (STATISTICA 7 Stat Software Inc., Tulsa, Oklahoma).

RESULTS

All the obtained results are expressed as means ± standard deviation (M±SD). Figure 1 shows a representative IRT of a foot affected by DD and ID, with the selected regions of interest. As reported in Figure 2, statistical analysis showed higher temperature values ($P<0.001$) in the central (R1) and interdigital area (R2) compared to lateral (R3) and medial (R4) areas of the hind feet of both healthy and diseased cows.

Differences were also found in the regions R1 and R2, with cows affected by DD and ID showing higher foot temperature values compared to healthy cows ($P<0.001$). In particular, the temperature of central areas of diseased cows hind feet showed a difference (∅) of 2.80 °C and an increase of 10.15% respect to healthy cows; whereas the temperature values recorded from

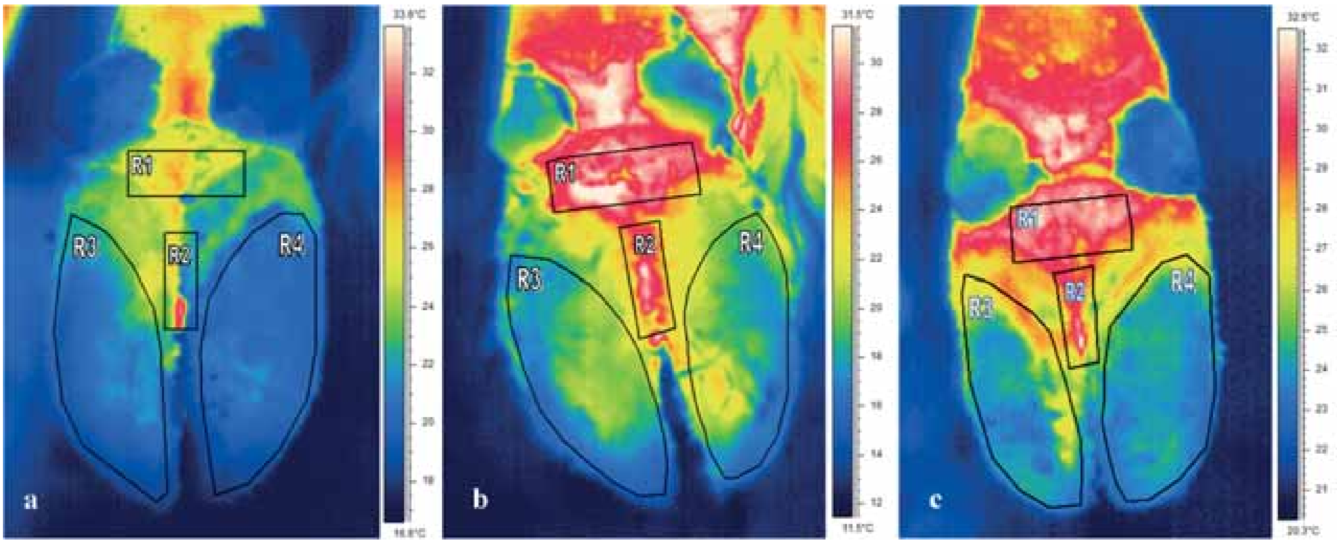

Figure 1 - Representative infrared thermal image of hind foot, with the regions of interest (R1, central area; R2, interdigital area; R3, lateral claw; R4, medial claw), of healthy cow (a), cow affected by digital (b) and interdigital (c) dermatitis - Thermal scale is included on the right side of the image.

the interdigital areas of diseased cows showed a difference (Δ) of 2.70 °C and an increase of 9.82% respect to healthy cows.

DISCUSSION

Efforts to reduce lameness in dairy cattle remain a priority as the industry strives to enhance animal welfare and productivity. Stress, especially during the transition period, is an undesirable aspect of livestock production as it often results in immune dysfunction and increased likelihood of infection[20]. Early lactation can be a seriously challenging event for the severe negative energy balance that high-yielding dairy cows can develop[21], this combination of stress, immune dysfunction and metabolic demand induced by parturition and beginning of milk production may help explain the increase in infectious foot lesions. This stress and immunosuppression interaction likely contributed to the high proportion of events diagnosed as foot rot[22]. In recent years, application of new diagnostic technologies in the dairy field such as non-reproduction related ultrasound and IRT has improved greatly[23], and the experiments on animals performed with the use of IRT have become very popular in livestock[14,24-27]. In some researches of skin temperature detection, it has been proved that the intensity of infrared radiation emitted is directly proportional to the metabolic processes occurring in some related surfaces and is associated with a simultaneous increase in blood supply to a given area[28]. The blood flow of the body surface depends on the relationship between the autonomic nervous system, the local vessel constriction and vessel-dilation mediators[29]. In literature, it is been reported that cow hooves infected with the foot-and-mouth disease virus IRT was applied, and show a marked increase in the temperature of sick animals before clinical symptoms appeared[30]. Although it is demonstrated that IRT was reliable in detecting elevated temperatures associated with foot lesions[10], external factors such as the environmental or facilities temperature and animal dirt may influence the foot temperature using IRT. Thoroughly cleaning cows' feet with water had a cooling effect[10]. In the present study, the IRT detections were done within the neutral zone for dairy cattle[31] and in closed barns at a controlled temperature without exposure to any direct sunlight or detectable airflow. In addition, all thermographic images were obtained after foot cleaning and drying and a five-minute timeout period was set to allow blood flow to return to its pre-wash state.

The results obtained in the present study indicated that the temperature measured in the four selected regions of foot showed different values both in cows affected by foot diseases than in

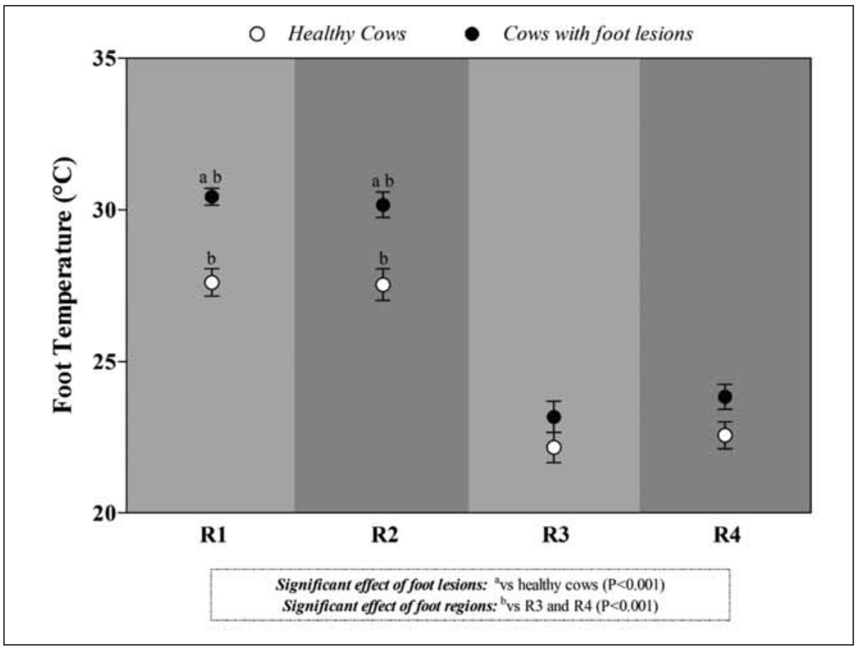

Figure 2 - Mean values ± standard deviation (±SD) of hind foot temperatures measured at the different regions of interest (R1, central area; R2, interdigital area; R3, lateral claw; R4, medial claw) in healthy cows and in cows with foot lesions together with the statistically significant differences found.

healthy cows. In particular, higher amount of infrared radiation, indicative of temperature, was emitted from the central and the interdigital areas of hind foot than from the lateral and medial claw in the hind foot. This could be due not only to the different vascularization and tissue metabolic activity of the foot regions, but also, and probably more importantly to the amount of keratinization, which may be associated to the lower temperatures found in the sole regions[32]. Cows affected by DD and ID showed higher temperatures in the central and interdigital regions of the foot compared to the foot of cows without diseases. Our findings agree with previous studies carried out on cows affected by hoof diseases reporting a rise in the values of temperature in cows with hoof diseases respect to healthy animals[10,26]. Inflammation or infectious conditions usually lead to a rise in the underlying circulation and tissue metabolic rate[25] resulting in a localized increase in the surface temperature of the affected areas, detected by IRT[17,33].

CONCLUSION

In conclusion, the results obtained in this study show that IRT could be a useful diagnostic tool in screening for DD and ID presence in dairy cows. In particular, DD and ID cause an increase in foot temperature measured by IRT in both the central and interdigital regions of affected feet, compared to feet without lesions. The study emphasizes the potential usefulness of IRT as a reliable, practical and non-invasive tool for the detection of hoof lesions in dairy cows, and suggests that IRT could contribute in defining the localization of increased inflammation and/or injury area. The application of IRT might be useful to veterinary podologists in detecting foot lesions. The early detection of foot diseases is likely to be valuable in the prevention of further progression and in early effective treatment. In this regard, the thermography recording could allow coordinating lameness monitoring plans to control and manage foot lesions to enhance dairy performance and animal welfare within each farm.

Disclosure statement

No conflict of interest was reported by the authors.

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References

1. Potterton S.L., Bell N.J., Whay H.R., Berry E.A., Atkinson O.C.D., Dean R.S., Main D.C.J., Huxley J.N. (2012). A descriptive review of the peer and non-peer reviewed literature on the treatment and prevention of foot lameness in cattle published between 2000 and 2011. Vet J, 193: 612-616.
2. International Lameness Committee. (2008). Dairy claw lesion identification. In Proc. 15th Int. Symp. 7th Conf. Lameness in Ruminants, Kuopio, Finland. Savonia University of Applied Sciences, Kuopio, Finland.
3. Logue D. (2011). Understanding bovine digital dermatitis. Vet Rec, 168: 212-213.
4. Becker J., Steiner A., Kohler S., Koller-Bähler A., Wüthrich M., Reist M. (2014). Lameness and foot lesions in Swiss dairy cows. Schweiz Arch Tierheilkd, 156: 71-78.
5. Britt J.S., Gaska J., Garrett E.F., Konkle D., Mealy M. (1996). Comparison of topical application of three products for treatment of papillomatous digital dermatitis in dairy cattle. J Am Vet Med Ass, 209: 1134-1136.
6. Read D.H., Walker R.L. (1996). Experimental transmission of papillomatous digital dermatitis (footwarts) in cattle. Vet Pathol, 33: 607.
7. Logue D.N., McNulty D., Nolan A.M. (1998). Lameness in the dairy cow: Pain and welfare. Vet J, 156: 5-6.
8. Leach K.A., Tisdall D.A., Bell N.J., Main D.C., Green L.E. (2012). The effects of early treatment for hindlimb lameness in dairy cows on four commercial uk farms. Vet J, 193: 626-632.
9. Flower F.C., Weary D.M. (2006). Effect of hoof pathologies on subjective assessments of dairy cow gait. J Dairy Sci, 89: 139-146.
10. Stokes J.E., Leach K.A., Main D.C., Whay H.R. (2012). An investigation into the use of infrared thermography (IRT) as a rapid diagnostic tool for foot lesions in dairy cattle. Vet J, 193: 674-678.
11. Paim T.P., Borges B.O., Lima P.M.T. (2013). Thermographic evaluation of climatic conditions on lambs from different genetic groups. Int J Biometeorol, 57: 59-66.
12. Schrank M., Bonsembiante F., Fiore E., Bellini L., Zamboni C., Zappulli V., Stelletta C., Mollo A. (2017). Diagnostic approach to fibrocystic mastopathy in a goat: termographic, ultrasonographic, and histological findings. Large Anim Rev, 23: 33-37.
13. Hovinen M., Siivonen J., Taponen S., Hänninen L., Pastell M., Aisla A.M., Pyörälä S. (2008). Detection of clinical mastitis with the help of a thermal camera. J Dairy Sci, 91: 4592-4598.
14. Alsaaod M., Schaefer A.L., Büscher W., Steiner A. (2015). The role of infrared thermography as a non-invasive tool for the detection of lameness in cattle. Sensors, 15: 14513-14525.
15. Perazzi A., Iacopetti I., Stelletta C., Fiore E. (2016). Bilateral glaucoma in a Tibetan goat: clinical and thermographic findings. Large Anim Rev, 22: 281-283.
16. McManus C., Tanure C.B., Peripolli V., Seixas L., Fischer V., Gabbi A.M., Menegassi S.R.O., Stumpf M.T., Kolling G.J., Dias E., Costa J.B.G. Jr. (2016). Infrared thermography in animal production: an overview. Comput Electron Agric, 123: 10-16.
17. Purohit R.C., Hudson R.S., Riddell M.G., Carson R.L., Wolfe D.F., Walker D.F. (1985). Thermography of the bovine scrotum. Am J Vet Res, 46: 2388-2392.
18. Bowers S., Gandy S., Anderson B., Ryan P., Willard S. (2009). Assessment of pregnancy in the late-gestation mare using digital infrared thermography, Theriogenology, 72: 372–377.
19. Toussaint-Raven E. (1989). Cattle foot care and claw trimming. Ipswich: Farming Press.
20. Overton T.R., Waldron M.R. (2004). Nutritional management of transition dairy cows: Strategies to optimize metabolic health. J Dairy Sci, 87: 105-119.
21. Fiore E., Perillo L., Piccione G., Gianesella M., Bedin S., Armato L., Giudice E., Morgante M. (2016). Effect of combined acetylmethionine, cyanocobalamin and α-lipoic acid on hepatic metabolism in high-yielding dairy cow. J Dairy Res, 83: 438-441.
22. DeFrain J.M., Socha M.T., Tomlinson D.J. (2013). Analysis of foot health records from 17 confinement dairies. J Dairy Sci, 96: 7329-7339.
23. Banzato, T., Fiore, E., Morgante, M., Manuali, E., Zotti, A. (2016). Texture analysis of B-mode ultrasound images to stage hepatic lipidosis in the dairy cow: A methodological study. Res Vet Sci, 108: 71-75.
24. Bortolami A., Fiore E., Gianesella M., Corrò M., Catania M., Morgante M. (2015). Evaluation of the udder health status in subclinical mastitis affected dairy cows through bacteriological culture, somatic cell count and thermographic imaging. Polish J Vet Sci, 18: 799-805.
25. Alsaaod M., Syring C., Dietrich J., Doherr M.G., Gujan T., Steiner A. (2014). A field trial of infrared thermography as a noninvasive diagnostic tool for early detection of digital dermatitis in dairy cows. Vet J, 199: 281-285.
26. Alsaaod M., Büscher W. (2012). Detection of hoof lesions using digital infrared thermography in dairy cows. J Dairy Sci, 95: 735-742.
27. Stelletta C., Gianesella M., Vencato J., Fiore E., Morgante M. (2012). Thermographic applications in veterinary medicine. In: Prakash, R.V. (ed) Infrared Thermography. 117-140, In Tech, China.
28. Fita K., Dobrzy ski M., Całkosi ski I., Dudek K., Bader-Orłowska D. (2007). The usefulness of the thermography in medical-dental diagnostic - the author's experiences. Ann Acad Med Stetin, 53: 34-38.
29. Całkosi ski I., Dobrzy ski M., Halo A., Fita K., Całkosi ska M., Majda J. (2007). Humoral-circulatory response in the somato-vegetative reflex caused by pain factors. Postepy Hig Med Dosw, 61: 331-337.
30. Rainwater-Lovett K., Pacheco J.M., Packer C., Rodriguez L.L. (2009). Detection of foot-and-mouth disease virus infected cattle using infrared thermography. Vet J, 180: 317-324.
31. Roenfeldt R. (1998). You can't afford to ignore heat stress. Dairy Herd Management 35: 6-12.
32. Rodríguez A.R., Olivares F.J., Descouvieres P.T., Werner M.P., Tadich N.A., Bustamante H.A. (2016). Thermographic assessment of hoof temperature in dairy cows with different mobility scores. Livest Sci, 184: 92-96.
33. Gianesella M., Arfuso F., Fiore E., Giambelluca S., Giudice E., Armato L., Piccione G. (2018). Infrared thermography as a rapid and non-invasive diagnostic tool to detect inflammatory foot diseases in dairy cows. Pol J Vet Sci, 21: 299-305.