INFRARED THERMOGRAPHY AS A TOOL TO STUDY THE MILKING PROCESS: A REVIEW

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Abstract

This review presents infrared thermography (IRT) as a tool studying and evaluating the milking process. IRT is a non-invasive and non-contact heat-detecting technology, an infrared camera measures and images the infrared radiation emitted from an object. A specially analysing software program evaluates the thermal images (thermograms). Although IRT is applied less frequently to the study of the milking process, present results show the potential of this measuring method. Generally, IRT is a suitable tool for early detection and screening of mastitis, and can be useful for studying and evaluating the effects of different milking technique on teats and udders. Important information can be produced where the possibilities diagnostic techniques have been exhausted.

Keywords: thermographic method, milking, teat, udder, mastitis

INTRODUCTION

Milking is an important process in farming. Different milking routines, and the very fact of using machine milking, can affect the health and welfare of animals because in this process an extremely sensitive organ, i.e. the mammary gland, comes into direct contact with the milking machine. The teats are the most stressed part of the udder, because milking changes their condition. Repeated teat compressions may cause mechanical and circulatory changes in teat tissues and hyperaemia in the teat wall (Hamann, 1992; Isaksson and Lind, 1992; Burmeister et al., 1998, Zecconi et al., 2000). Such changes may even lead to pathological traumatisation manifested by, for example, congestion, oedema, cracks in mucous membrane, induration. There are a number of factors in milking that influences the condition of the teats. Literary sources emphasise the importance of the milking vacuum, and also the pulsation rate and the quality of the teat cups. Assessment of the teats and udder before and after milking is usually based on visual observations. For such assessments, a cutimeter (Isaksson and Lind, 1992) or a classification system (Neijenhuis, 1998; Rasmussen and Larsen, 1998, Neijenhuis et al., 2000) or ultrasonographic scanning (Neijenhuis, 2004) are used.

Bovine mastitis infection is a widespread problem in the dairy industry. This common affliction is difficult to treat, and its effects include reduced milk quality resulting in lower milk prices, as well as reduced output and increased veterinary costs for dairy management. Early detection of mastitis can improve profits through increased milk production, decreased milk dumped due to treatment, reduced veterinary and drug costs, reduced labour costs, fewer culling and death losses and improved quality premiums (Willits, 2005). Detection of mastitis is generally provided by electrical conductivity (Norberg, 2005) or by somatic cell counts (SCC), the California mastitis test (CMT) or bacterial isolation and identification (Timms, 2004). New techniques are, however, being sought for an early detection of mastitis in the dairy industry.

Infrared thermography

Infrared thermography (IRT) is a modern, non-invasive and safe technique of thermal profile visualisation. Every object on the earth generates heat radiation in the infrared part of the light spectrum, the intensity and spectrum distribution of which depend on the temperature of the mass and the radiation properties of its surface layer. Using a thermographic scanning equipment (a thermographic camera) able to detect this type of radiation, even minute changes in temperature can be accurately monitored. The data obtained by scanning is computer-processed, and shown in the form of temperature maps that provide for a detailed analysis of the temperature field.

An infrared camera measures and images the infrared radiation emitted from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature. However, the radiation measured by the camera does not only depend upon the temperature of the object, but is also a function of its emissivity. Radiation also originates from the surroundings and is reflected by the object. The radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere. To measure temperature accurately, it is therefore necessary to compensate for the effects of a number of the different radiation sources. This is done on-line automatically by the camera. However, the following object parameters must be supplied for the camera: the emissivity of the object, the reflected temperature, the distance between the object and the camera and the relative humidity.

The thermographic method has found numerous applications not only in industry (e.g. building, the military and police, energetics) but also in human and veterinary medicine (Yang & Yang, 1992; Denoix, 1994; Hilsberg et al., 1997; Harper, 2000; Markel & Vainer, 2005). In living organisms, changes in vascular circulation result in an increase or decrease in their tissue temperature, which is then used to evaluate the situation in that area (Harper, 2000). For example, heat generated by inflammation is transmitted to the overlying skin via increased capillary blood flow, and is dissipated as infrared energy. By using an infrared camera and a specially developed analyzing software program, this infrared energy can be measured (Embaby et al., 2002). One major advantage of this method is the fact that it does not require direct physical contact with the surface monitored, thus allowing remote reading of temperature distribution (Speakman & Ward, 1998).

There are, however, certain limitations and factors that need to be considered when using IRT. Thermograms must be collected out of direct sunlight and wind currents. The surface should be free of dirt, moisture and foreign material. The effect of weather conditions, circadian and ultradian rhythms are also factors that need to be considered and require further investigation as part of validating IRT.

Infrared thermography in the milking process

Thermographic measurements of the milking process have been taken by Hamann (1985), who investigated the temperature responses of the udder to machine milking. This study showed that conventional milking machines may cause an increase of the teat-end temperature by 2°C. Caruolo et al. (1989) studied the relationship between the internal and surface temperatures of the mammary gland and the temperature of milk in goats. The authors used IRT to measure the surface temperature of the udder and teats and found an increase in temperature following machine milking. This supports the findings of Eichel (1992), who reported increased teat temperature after milking in 90% of dairy cows, although the evaluation of the milking used did not show any significant damage to the teats. Paulrud et al. (2002) used IRT to evaluate milking-induced alternations in teat tissue fluid circulation and they obtained similar results. The authors concluded that IRT is useful for studying and evaluating the effects of various milking techniques on teat fluid dynamics.

Kejik and Maskova (1989) and Malik et al. (1989) took udder thermograms and evaluated the relationship between the traumatised zones and the quality of the teat rubber. The thermographic study showed that milking may cause traumatisation in certain zones of the udder and teats. The authors pointed out that such traumatisation in the course of milking may be the cause of mastitis. IRT was also used by Maskova (unpublished) in her evaluation of a prototype of a new milking machine. The evaluation was based on an assessment of teat surface temperatures during milking and the shape of the teat rubber used in the new type of milking machine was not found to significantly stress the tip of the teat. Kunc et al. (1999) and Kunc et al. (2000a) investigated the dynamics of teat temperature changes in relation to vacuum changes (40 kPa vs. 45 kPa). After evaluation of thermograms it was found that a 40 kPa vacuum evoked lower teat temperatures than a 45 kPa vacuum. Further, Kunc et al. (2000b) used IRT to monitor udder temperature responses in healthy dairy cows under standard operating conditions in an autotandem milking parlour, in which all technical specifications complied with the standard. A comparison of all thermograms showed that milking caused significant changes in teats, particularly in those which were in direct contact with the milking machine and were subject to a significant stress. Teat temperature was increased by an average of 2.62°C. Similar results were reported by Barth (2000). Kunc et al. (2000c) compared rubber liners from two producers. The results showed that milking increased the temperature of teats. The highest values were obtained immediately after milking. This trend was recorded in liners from both producers. The differences in the temperature states of teats were, however, not significant between the producers. New liners (immediately after exchange) increased the temperature of teats more than old liners (immediately before exchange), but the differences were not significant. Schmidt et al. (2004) found that cows with a high milk production had higher udder temperatures pre- and post- milking than low producing cows. These data suggest that IRT may have value as a diagnostic tool for assessing udder function in relation to temperature gradient changes and the level of milk production. Paulrud et al. (2005) obtained similar results.

Kunc et al. (2002) studied by means of the thermographic method the effect on teats of machine milking (vacuum 42.6 kPa) as compared to a suckling calf. Generally, teat temperature showed a significant increase after milking and suckling. The effect of calf suckling on the temperature of teats was dependent on age. Calves in the colostrum period (age 5 days) stressed teats significantly less than older calves (calves in the milk period, age 20 days). Further, these older calves stressed teats more than machine milking.

Berry et al (2003a) used IRT to investigate the effects of environmental factors on daily variation in udder temperature. The authors found a distinct circadian rhythm in udder temperature and significant increase in udder temperature caused by exercise. But the daily variation in udder temperature was found to be smaller than the rise in temperature resulting from an induced mastitis response. They concluded that IRT has potential as an early detection tool for mastitis if it is combined with monitoring of environmental factors.

Recent studies have focused on the use of IRT to detect mastitis much earlier than was previously possible. Scott et al. (2000) found that inflammation could be detected from temperature differences by using IRT earlier with either bovine serum albumin or somatic cell counts. The concentration of bovine serum albumin peaked at 6 h post induction, whereas IRT temperature increases were evident within 1 h post-induction. Also Berry et al. (2003b) proved that IRT shows potential as an early detection method for mastitis. This supports the findings of Willits (2005) Kennedy (2004), who found that mastitis infections cause udder surface temperature to rise often before other clinical signs are observed. In experimentally induced mastitis, a rise of 2.3°C was recorded. She recommended that cows be walked past an infrared camera, which would photograph the rear of their udder. The camera and its associated computer would identify and recorded cows whose udder surface temperatures were higher than normal. Herd management would follow up with further assessment and possible treatment of cows flagged by the system.

CONCLUSIONS

The above examples prove conclusively that IRT can produce important information where the possibilities of conventional diagnostic techniques have been exhausted. This measurement method has value as a diagnostic tool for assessing udder function and can be considered a useful method for indirect and non-invasive evaluation of the condition of teats and udders. Evaluation of IRT may be promising for detection of mastitis, and shows potential as an early detection method for mastitis.

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REFERENCES

Barth K. (2000): *Basic investigations to evaluate a highly sensitive infrared-thermograph-technique to detect udder inflammation in cows.* Milchwissenschaft-Milk-Science International 55, 607 – 609.

Berry R.J., Kennedy A.D., Scott S.L., Kyle B.l., Schaefer A.L. (2003a): *Daily variation in the udder surface temperature of dairy cows measured by infrared thermography: potential for mastitis detection.* Canadian Journal of Animal Science, 8, 687 – 693

Berry R.J., Kennedy A.d., Scott S.L., FULAWKA D., Hernandez F.I.L, Schaefer A.L. (2003b): *The potential of infrared thermography as an early detection method for mastitis.* Seasonal effects on predictability. Journal of Animal Science, 81, Journal of Dairy Science 86, 85

Burmeister J. E., Fox L. K., Hillers J. K., Hancock D. D. (1998): *Effect of premilking and postmilking teat disinfectants on teat skin condition*. Journal of Dairy Science, 81, 1910 – 1916.

Caruolo E. V., Jarman R.F., Dickey D. A. (1989): *Milk temperature in the claw piece of the milking machine and mammary surface temperature are predictors of internal mammary temperature in goats*. Journal of Veterinary Medicine, 37, 61-67.

Denoix J. M. (1994): *Diagnostic techniques for identification and documentation of tendon and ligament injuries*. Veterinary Clinics of North America: Equine Practice, 10, 365-407.

Eichel H. (1992): *Temperature of teat skin in dairy cows milked in piped milking parlor*. Monatshefte für Veterinarmedizin, 47, 193 – 195.

Embaby S., Shamaa A. A., Gohar H. M. (2002): *Clinical assessment of thermography as a diagnostic and prognostic tool in horse practice*. In: Proceedings of Inflammation 2002, Orlando, USA, 30 – 36.

Hamann J. (1985): *Infection rate as affected by teat tissue reactions due to conventional and non-conventional milking systems*. Kieler Milchwirtschaftlich Forschungsberichte, 37, 426 – 430.

Hamann J. (1992): *Stimulation and teat tissue reaction.* Kieler Milchwirtschaftlich Forschungsberichte, 44, 339 – 347.

Harper D.L. (2000): *The value of infrared thermography in the diagnosis and prognosis of injuries in animals.* In: Procedings of. Inframation 2000, Orlando, USA,115 – 122.

Hilsberg S., Goltenboth R., Eulenberg K. (1997): *Infrared thermography in zoo animals: preliminary experiences from its use in pregnancy diagnosis.* In: Proceedings of. 38. Internationalen Symposium über die Erkrankungen der Zoo- und Wildtiere, Zurich, Schweiz, 187 – 190.

Isaksson A., Lind O. (1992): *Teat reactions in cows associated with machine milking.* Journal of Veterinary Medicine, 39, 282 – 288.

Kejík C., Mašková A. (1989): T*hermographic measurements of teat surface temperature during machine milking.* Živočišná výroba, 35, 225-230.

Kennedy, A. (2004): *Mastitis detection using infrared thermography*. Western Dairy Digest, 5 (4), 15

Kunc P., Knížková I., Koubková M. (1999): *The influence of milking with different vacuum and different design of liner on the change of teat surface temperature*. Czech Journal of Animal Science, 44, 131 – 134.

Kunc P., Knížková I., Koubková M., Flusser J., Doležal O. (2000a): *Thermographic observation of the mammary gland responses to machine milking in dairy cows*. Physiological Research, 4, 21.

Kunc P., Knížková I., Koubková M., Flusser J., Doležal O. (2000b): *Machine milking and its influence on temperature states of udder*. Czech Journal of Animal Science, 45, 1 – 15.

Kunc P., KnížkováI., Koubková M., Flusser J., Doležal O. (2000c): *Comparison of teat rubber* *liners by means of temperature states of teats. Research in Agriculture Engineering*, 46, 104 – 107.

Kunc P., Knížková I., Koubková M. (2002): T*eat stress by calf suckling and machine milking*. Folia Veterinaria, 46, 48 – 49.

Malík K., Mašková A., Vévoda J. (1989): *A thermovision study of the rubber teat cup function*. Plastics and Rubber - Special Issue, 49-51.

Markel A. L., Vainer B. G. (2005): *Infrared thermography in diagnosis of breast cancer* (review of foreign literature). Terapevticheskii Arkhiv, 77, 57 – 61.

Neijenhuis F. (1998): *Teat end callosity classification system*. In: Proceedings of 4th International Dairy Housing Conference, ASAE, 117 – 123.

Neijenhuis F., Barkema H.W., Hogeveen H., Noordhuizen J.P.T.N. (2000): *Classification and longitudinal examination of callused teat ends in dairy cows*. Journal of Dairy Science, 83, 2795 – 2804.

Neijenhuis F. (2004): *Teat condition in dairy cows.* Ponsen & Looijen BV, Wageningen, the Netherlands, 191.

Norberg E. (2005): *Electrical conductivity of milk as a phenotypic and genetic indicator of bovine mastitis.* Livestock Production Science, 96, 129 – 139.

Paulrud O., Clausen S., Andersen P.E., Bjerring M., Rasmussen, M.D. (2002): *Infrared thermography to evaluate milking induced alterations in teat tissue fluid circulation*. Journal of Animal Science, 80, Journal of Dairy Science, 85, 84.

Paulrud O., Clausen S., Andersen P. E., Bjerring M., Rasmussen, M.D. (2005): *Infrared thermography and ultrasonography to indirectly monitor the influence of liner type and overmilking on teat tissue recovery.* Acta Veterinaria Scandinavica, 46, 137 – 147.

Rasmussen M.D., Larsen, H.D. (1998): *The effect of post milking teat dip and suckling on teat condition, bacterial colonization and udder health*. Acta Veterinaria Scandinavica, 39, 443 – 452.

Schmidt S., Bowers S., Dickerson T., Graves K., Willard S. (2004): *Assessments of udder temperature gradients pre- and post- milking relative to milk production in Holstein cows as determined by digital infrared thermography.* Journal of Animal Science, 82, Journal of Dairy Science, 83, 460 – 461.

Scott S. L., Schaefer A.L., Tong A.K.W., Lacasse P. (2000): *Use of infrared thermography or early detection of mastitis in dairy cows.* Canadian Journal of Animal Science, 70, 764 – 765.

Speakmen J. R., Ward S. (1998): *Infrared thermography: principle and applications.* Zoology, 101, 224 – 232.

Timms L. (2004): *Mastitis Diagnosis.* Western Dairy Digest, 5, 10 – 11.

Willits S. (2005): *Infrared thermography for screening and early detection of mastitis infections in working dairy herds.* In: Proceedings of . Inframation 2005, Las Vegas, USA, 1 – 5.

Yang W., Yang P. P. T. (1992): *Literature survey on biomedical applications of thermography.* Bio-medical Materials and Engineering, 2, 7 – 18.

Zecconi A., Hamann J., Bronzo V., Moroni P., Giovannini G., Piccini R. (2000): *Relationship between teat tissue immune defences and intramammary infections.* Advances in Experimental Medicine and Biology, 480, 287 – 293.

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