Effects of trimming on the thermographic pattern of claw sole in dairy cows

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SUMMARY

Lameness is one of the most significant health, economic and welfare issues in dairy farms. In the present study potential usefulness of infrared thermography (IRT) as a non-invasive instrument for rapidly screening the claw sole temperature alterations between baseline (before trimming) and after trimming was investigated. For this purpose, this study was aimed to reveal the effect of claw trimming on claw sole temperature by using infrared thermography (IRT). One hundred thirty IRT observations from the hind legs of non-lame, healthy cows were collected and examined from 65 cows. The maximum (Tmax), average (Tave), and minimum (Tmin) temperatures of the claw sole and the temperature difference (ΔT) between the lateral and medial claws were examined on the baseline and after trimming. Claw temperature values were evaluated for normality using the Shapiro Wilk test. Paired t-test was used for comparing results with normal distribution while Wilcoxon's signed-rank test was also used for nonparametric comparisons. Average baseline and after trimming solar surface temperature values on lateral claws were determined as 19.91±2.67°C and 21.49±3.43°C, respectively. The solar surface temperature values on medial claws were baseline 19.96±2.52°C and after trimming 20.98±2.83°C. There were statistically significant differences between baseline with after trimming solar surface temperatures of lateral (Tmax: P=0.005; Tave: P<0.001; and Tmin: P=0.005), and medial claws (Tave: P<0.001). After trimming, claw sole temperature values between the lateral and medial were statistically significant (Tmax: P=0.020; Tave: P=0.039; and Tmin: P=0.004). Medial-lateral claw temperature differences between baseline with after trimming values were also statistically significant (ΔTmax: P=0.050; ΔTave: P=0.001; and ΔTmin: P=0.019). In conclusion, claw trimming increased the solar surface temperature values of the claw sole in this study. In the present study, claw sole temperature values were relatively higher on lateral than medial claws both for the baseline and after trimming. In future studies, the reliability of the current method can be demonstrated by comparing thermography to other evaluation methods.

KEY WORDS

Claw trimming, dairy cow, IRT, thermography.

INTRODUCTION

Dairy cow lameness has a negative effect on welfare and dairy production, as well as decreasing reproductive capacity and increased culling rates in dairy farms[1,2]. Claw disorders and lameness may cause considerable suffering for the cows because most cases of lameness are long-lasting and painful[3]. It is very important to identify lameness and claw lesions as early as possible to eliminate yield loss and reduce recovery time. The most common way of detecting lameness is to use locomotion scores[4]. Locomotion scores may not be sensitive to detecting all related claw lesions[5]. Recent studies reported electronic lameness detection by recording dairy cattle locomotion parameters such as gait and weight distribution in walking or standing[6,7,8]. Routine claw trimming, from the view of the solar surface of claws, is a good management practice to detect and prevent claw diseases and treat lesions such as sole hemorrhages, sole ulcers, thin sole, white line separations/diseases, and heel erosion[9]. However, over-trimming may predispose to claw injuries and disorders due to the thin sole[10]. Therefore, methods for assessing claw temperature measurements should be investigated as an alternative and assisting tool to trimmers with revealed temperature ranges of healthy claws.

Infrared thermography (IRT) is a non-invasive diagnostic technique that can measure the temperature of an object by emitted radiation and displays the information called a thermogram[11,12,13]. While the temperature of skin and extremities is determined by the underlying circulation and metabolism rate, some conditions such as inflammation may alter blood flow and surface temperature[14]. Thus, variation and superficial venous changes are related to inflammation can be measured and monitored by IRT[15]. Infrared thermography has been applied

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in equine medicine in the diagnosis of foot and leg problems and as an aid in the detection of lameness or inflammation in horses[12]. In dairy cows, IRT has been used to detect digital and interdigital dermatitis and inflammatory foot diseases[15,16]. Therefore, the objective of this study was to evaluate the potential role of using IRT to measure claw sole temperature differences between baseline and after claw trimming in healthy cows. In this study, the authors expected to observe temperature differences (minimum-average-maximum and temperature differences between claws) between lateral and medial claw sole temperatures baseline and after trimming.

Materials and methods

Animals and housing

The study was conducted on a commercial dairy farm in California with about 9.000 Holstein lactating cows. Non-lame, healthy cows were enrolled in the study as their claws were trimmed prior to dry-off. Sixty-five healthy and second parity Holstein cows (n=65) were selected in late lactation (228±8.23 days in milk). The present study included cows that exhibited no symptoms of systemic disease, claw lesions, or lameness. Cows were receiving preventive claw trimming once a year by a professional claw trimmer.
Cows were housed in a free-stall dairy barn. The flooring was grooved concrete and sand bedding. The alley next to the feed bunk (3.50 m) was covered with a 1.5-cm thick flat rubber mat. Alleys were cleaned 15 times a day with an automatic scraper. Cows were fed a total mixed ration consisting of approximately 55% forage (corn silage, haylage, alfalfa hay, and wheat straw) and 45% concentrate (cornmeal, soybean meal, canola, and cottonseed). The feeding and water troughs were ad libitum. The cows were milked twice daily at 05:30 and 16:30 h in a double milking parlor.

Experimental design

Infrared thermography images (thermograms) of enrolled cows' hind legs were obtained daily before the afternoon milking. All cows walked into the trimming chute. Prior to the thermograms, claws were cleaned with a pressure washer to remove dirt. Following washing, the claws were dried using paper towels. The hind leg claws of the cows were trimmed by a professional claw trimmer by using a cutting disc. All thermograms were captured in the claw trimming area located next to the milking parlor, eliminating direct sunlight in the afternoon. All thermograms were accomplished in three days under the same condition and same time frame (13:00-18:00).

Clinical claw examination

Claw lesions of the hind lateral and medial claws were examined during the routine herd trimming check. The diagnoses of claw lesions were performed before afternoon milking based on inspection, palpation, and evaluation of smells and pain re-

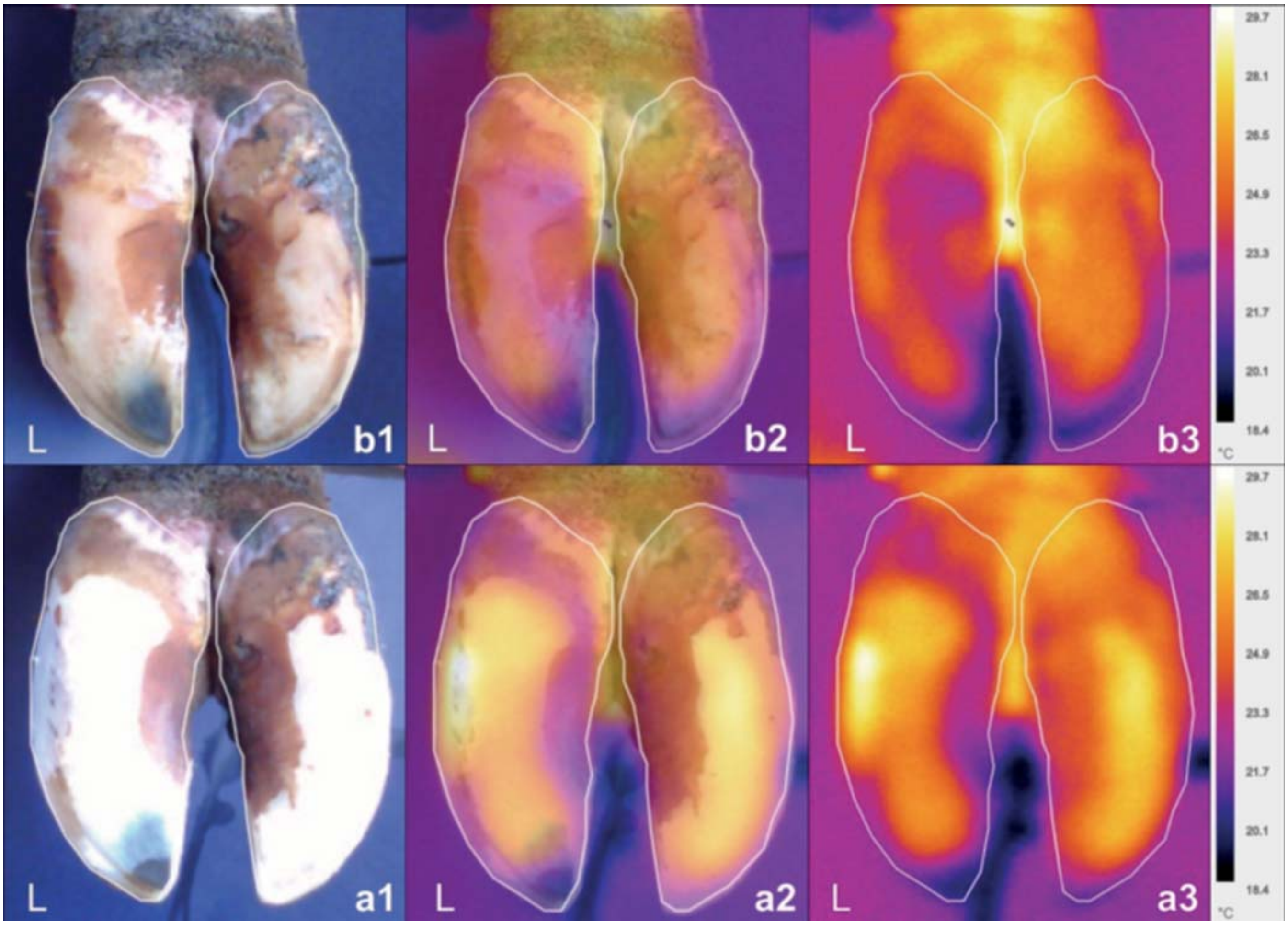

Figure 1 - Thermographic images (thermogram) of the claw's solar surfaces (sole view area of the lateral and medial claw) baseline (b1: normal view, b2: hybrid view, and b3: thermographic view) and after trimming (a1: normal view, a2: hybrid view and a3: thermographic view); L = Lateral.

actions with gooseneck claw tester as described by Espinasse et al. (1984)[17]. All visually lame and any disease-diagnosed animals were excluded from the study due to the study design.

Thermal imaging

Thermograms were obtained with TiR125 Thermal Imager (Fluke IR-Fusion Technology, Everett, WA, United States; emissivity value was set at 0.95 with a precision of ±0.01°C) to assess the maximum, average, and minimum surface temperatures of the claw sole. Thermograms were analyzed using the software SmartView 3.1.82.0 (Fluke IR-Fusion Technology, Everett WA, United States). The infrared camera was calibrated by the company and the calibration was tested every day by the thermal reading of an object of known temperature daily. Thermograms of all claws were scanned from solar aspects (Figure 1) while cows were standing on rubber mats placed on a hydraulic trimming chute. Legs were lifted with a hydraulic trimming chute, and all scans were performed at the same distance (0.5 m). The solar view area (Figure 1, the area inside the white line drawn by the first author (IA) for each claw via software program) of the lateral and medial claw in each image was measured with the help of the same software tool. All thermograms were captured in the claw trimming area, with no direct sunlight or detectable airflow, and they were taken immediately before and after trimming. Images were calibrated by relating each of the shades of gray on the digitized image to a specific temperature for all pixels. These values then were mapped to degrees centigrade, and the maximum (**Tmax**), average (**Tave**), and minimum (**Tmin**) temperatures of the solar area in each lateral and medial claw were determined before and after trimming. The software program [Smart View 3.1.82.0 (Fluke IR-Fusion Technology, Everett WA)] was adjusted to remove the effect of outlier maximum temperatures related to extraneous particles or too few (<5) pixels exhibiting the maximum temperature, the relative maximum temperature was calculated. The temperature differences (ΔT) between the sole of the lateral and the medial claws were also calculated via deducted from the «Medial claw sole temperature» to «Lateral claw sole temperature». Thus maximum (ΔTmax=Tmax medial - Tmax lateral), average (ΔTave=Tave medial - Tave lateral), and minimum (ΔTmin=Tmin medial - Tmin lateral) temperatures were obtained with fewer variables.

Statistical analyses

The statistical analyses were performed using SPSS 22 (IBM Corp. Armonk, NY, United States) statistical package program. Descriptive statistics were performed to reveal the mean and standard deviation (SD) of every variable. Outcomes were checked for normality using the Shapiro Wilk test. For observing the effect of trimming on claw sole temperature, pre-trimming values of each parameter (Tmax-Tave-Tmin) and the temperature differences between the sole of the lateral and the medial claws (ΔTmax-ΔTave-ΔTmin) were determined as the predictor variables while after trimming values were determined as predicted variables. Similarly, medial claws were determined as the predictor variables to observe the temperature differences (ΔT) of lateral and medial claws before and after trimming, while lateral claws were determined as predicted variables. Before and after trimming average temperatures of lateral claws, ΔTmax, ΔTmin, and before and after trimming average temperatures of lateral claws were determined as normal distribution, and paired t-test was used for parametric comparison. Other parameters with apparently non-normal distributions were compared with Wilcoxon's signed-rank test. The significance level was set at $P<0.05$. The means and standard deviations are presented in Table 1, Table 2, and Table 3.

RESULTS

Significant differences were found for Tmax ($P=0.005$), Tave ($P<0.001$), and Tmin ($P=0.005$) of lateral claws' baseline and after trimming thermograms (Table 1). Only Tave of medial claws was found statistically significant ($P<0.001$) between baseline and after trimming thermograms. There was no statistical significance in baseline values (Tmax, Tave, and Tmin) between the lateral and medial claw sole thermograms ($P>0.05$). However, after trimming, statistical differences were found on Tmax ($P=0.020$), Tave ($P=0.039$), and Tmin ($P=0.004$) values between lateral and medial claw thermograms (Table 2). The maximum (ΔTmax), average (ΔTave), and minimum (ΔTmin) temperature differences between medial and lateral claws ("medial claw solar surface temperature" - "lateral claw solar surface temperature") showed a statistical significance (ΔTmax: $P=0.050$, ΔTave: $P=0.001$, and ΔTmin: $P=0.019$) between baseline and after trimming values (Table 3). The negative values were observed after trimming ΔTmax (-1.21±4.01˚C), ΔTave (-0.51±2.43˚C), and ΔTmin (-0.41±1.02˚C) and baseline trimming ΔTmax (-0.29±2.67˚C) since the lateral claw temperature values were higher than the medial claws (Table 3).

DISCUSSION

The claw trimming leads to an increase in the surface temperature of the lateral and medial claw soles (Table 1). The sole temperatures of lateral and medial claws were statistically significant ($P<0.05$) after trimming compared to baseline values (Table 2). Similarly, there was a statistically significant increase ($P\leq0.05$) in the temperature differences of medial and lateral claws (ΔT) between baseline and after trimming (Table 3). The authors investigated the thermal alterations on the sole surface of cow claws to detect a difference between baseline and after claw trimming. Our findings may demonstrate a new approach to preventive hoof trimming by focusing on the sole aspect (always faced and seen by the hoof trimmers) of the claws using IRT.

IRT studies conducted on dairy cattle may be affected by cow level factors (inflammation, diseases, etc.) or ambient factors (sunlight, airflow, other heat sources, etc.) in dairy farms[18]. In the present study, we tried to establish the best possible study design for collecting data for avoiding or reducing that mentioned and preventable factors[18].

Previously, lower sole horn thickness of the hind feet lateral claws[9,19,20], uneven load distribution[9], and length difference of paired digits[21] were considered with the key practical claw trimming to reduce stress on the lateral hind claws and to redistribute some of the strain to the medial claw[22,23]. In the present study findings, ΔT values were more in favor of an increase in lateral claws. Lateral claw sole temperatures increased more than medial claws by hoof trimming and the temperature differences (maximum, average, and minimum) were statistically higher (ΔT_{Max}: $P=0.050$, ΔT_{ave}: $P=0.001$, ΔT_{Min}: $P=0.019$) after trimming compared to baseline trimming values. It may be interpreted

Table 1 - Maximum (Tmax), average (Tave), and minimum temperature (Tmin) (°C; means and standard deviations) changes (means and standard deviations) between baseline and after trimming of lateral and medial claw solar area.

Temperatures of claw sole area (°C)	Lateral Claws (n=65)			Medial Claws (n=65)		
	BT (Mean ± SD)	AT (Mean ± SD)	P value	BT (Mean ± SD)	AT (Mean ± SD)	P value
Tmax	27.27±4.22	28.53±4.60	0.005	26.98±4.24	27.32±3.92	0.355
Tave	19.91±2.67	21.49±3.43	0.000	19.96±2.52	20.98±2.83	0.000
Tmin	15.93±2.10	16.41±2.50	0.005	15.95±2.19	16.00±2.27	0.958

BT: Baseline; AT: After trimming.

Table 2 - Comparison of medial and lateral claws solar surface maximum (Tmax), average (Tave), and minimum temperatures (Tmin) (°C; means and standard deviations) baseline and after trimming.

Temperatures of claw sole area (°C)	Baseline (n=65)			After Trimming (n= 65)		
	LC (Mean ± SD)	MC (Mean ± SD)	P value	LC (Mean ± SD)	MC (Mean ± SD)	P value
Tmax	27.27±4.22	26.98±4.24	0.291	28.53±4.60	27.32±3.92	0.020
Tave	19.91±2.67	19.96±2.52	0.506	21.49±3.43	20.98±2.83	0.039
Tmin	15.93±2.10	15.95±2.19	0.831	16.41±2.50	16.00±2.27	0.004

LC: Lateral claws; MC: Medial claws.

Table 3 - The temperature differences of claws (medial claw-lateral claw, means, and standard deviations) in maximum (ΔTmax), average (ΔTave), and minimum (ΔTmin) temperatures (°C; means and standard deviations).

Temperature Differences[1] (°C)	BT (n=65, Mean ± SD)	AT (n=65, Mean ± SD)	P value
ΔT_{Max}	-0.29±2.67	-1.21±4.01	0.050
ΔT_{Ave}	0.05±1.74	-0.51±2.43	0.001
ΔT_{Min}	0.01±1.32	-0.41±1.02	0.019

[1]Temperature differences (ΔT) of the claws (medial claw- lateral claw) between baseline and after trimming; a negative value indicates a lower medial claw surface temperature; BT: Baseline; AT: After trimming.

that these results may be indicating the possibility of encountering thin soles and/or over trimming. To this respect, ΔT values in this study can attribute to the difference, which has an important role in preventing thin sole and/or over trimming in both claws during hoof trimming. Moreover, compared to medial claws, Tmax, Tave, and Tmin temperatures of the lateral claw sole were significantly higher after trimming ($P<0.05$) in the present study. Nuss and Paulus (2006) reported a parallel finding that hind feet trimming could result in excessive lateral claw sole thinning[10]. Since the lateral claw bears more weight than the medial claw thus lateral claw wear is quicker[24]. This is offset by increased growth of the claw horn[25] and can be achieved by the proliferation of the corium cells, requiring increased blood and nutrient supply[26]. The higher temperature of lateral claws in this study may be triggered by these physiological conditions.

Thermographic identified hot spots occur at recognized weight-bearing sites, indicating injury or inflammation to the tissue[15,16]. In our data, especially considering after trimming temperatures, while maximum values may indicate local inflammation or any subclinical lesion of inner tissue of claw, minimum data may be indicated necrosis or low blood flow. Also, the higher average temperature may indicate a thin sole. That comment may be necessary for a call to more work to respond to a potential role of IRT on the diagnosis of subclinical or local inflammation or a claw disease. In our study, however, all animals were checked for lameness and claw lesions for achieving the healthy temperature range of claws by excluding all lame/sick cows. In this respect, this study may increase attention to achieve the normal temperature range of dairy cow claws in future studies.

In the current study, practical claw trimming in the cows was carried out by a skilled claw trimmer. Claw trimming was correlated with an increase in claw sole temperature in the study. This result is in line with the main principle of claw trimming. It is supporting the argument of van der Tol et al. (2004), who found that claw trimming affected weight-bearing and pressure distribution on the hind claws[22]. They stated that the load of the lateral claws in the hind feet was reduced from 80 percent (pre-trimming) to 70 percent (2 wk post trimming). This argument is correlated with our finding's fact that the after trimming lateral claws' solar surface Tmax (28.53±4.60˚C, P=0.020), Tave (21.49±3.43˚C, P=0.039), and Tmin (16.41±2.50˚C, P=0.004) were statistically higher than in the medial claws. Additionally, this temperature favor in lateral claws can be explained with the previous study van Amstel and Shearer (2006) reported that lateral claws were thinner than medial claws[20].

In the present study, the temperature alterations between baseline and after trimming of claw sole have been observed and reported. Further analyses to predict the normal temperature range of healthy claws can be helpful in their decisions to trimmers and veterinarians for utilizing IRT as a non-invasive, automated diagnosis tool on trimming and claw health checks.

CONCLUSIONS

We conclude that there was a significant temperature increase in claw sole temperatures between the paired hind claws by claw trimming. Lateral claw temperatures were relatively higher than medial claws baseline and after trimming. Lateral and medial claw temperatures can be evaluated and guided by the trimmers during and after trimming as they may be indicators of conditions such as weight-bearing and thin soles. Future studies may benefit from our current results in the hope of determining the temperature range of healthy claws on solar view. Also, the reliability of the current method can be asserted by contrasting thermography with other evaluation methods in future studies to avoid thin soles and/or over-trimming.

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