

Article

Evolution of Local Temperature after Thermal Disbudding in Calves: A Preliminary Study

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Abstract: Thermal disbudding and dehorning are very common techniques employed for the removal of horn buds in dairy calves. Infrared thermography was used to determine the local temperature before the thermal disbudding procedure, five seconds into the procedure, and two hours after the procedure was finished. Background: Some studies have used thermography to evaluate the local temperature after applying a hot-iron device to produce a permanently visible mark on calves. Our objective was to evaluate the local temperature and the thermal pattern following hot-iron disbudding and to certify that the local temperature reaches the value at which tissues undergo necrosis. Methods: Calves ($n = 36$) were subjected to thermography scanning of the horn bud area before the thermal disbudding procedure, five seconds into the procedure, and two hours after the procedure was finished. Results: Differences in local temperature before and after hot-iron disbudding were observed. The mean and the maximum temperature of the horn bud area increased in value after the disbudding procedure, leading to changes in the overall thermal pattern. Conclusions: Thermography of the horn bud area before and after thermal disbudding allows for the identification of changes in local temperature and thermal pattern. The local temperature obtained after the hot-iron disbudding procedure exceeds the temperature required for tissue necrosis. Thermographic evaluations help us to effectively discriminate between superficial burns and deep burns such as those induced by hot-iron disbudding.

Keywords: thermal disbudding; infrared thermography; calves



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1. Introduction

Dairy calves are often subjected to disbudding to prevent the growth of horns, as horns can pose risks of injury to other animals or farm personnel [1]. Disbudding and dehorning are common practices in cattle farming, with various tools developed for both the destruction of horn bud tissue, such as cautery or scalpel, and for the removal of horns, such as metal wire and electrical saws [2,3]. The disbudding procedure can lead to physiological and behavioral changes if no pain relief is provided [1,3]. Cautery disbudding is typically performed on calves within the first four to six weeks of life [4–6]. This involves destroying the horn bud by searing it with a heated bar with a concave tip, which heats the bud and surrounding tissue for about twenty seconds [2,6]. Temperatures around 47 °C seem to effectively kill all types of skin cells from the thoracic area, with damage rates doubling with each degree rise in temperature between 44 °C and 51 °C [7,8].

Disbudding is typically conducted when horn buds are easily palpable and measure between 5 to 10 mm in length, usually around four weeks of age; after this size, disbudding becomes impractical, and dehorning becomes necessary [4,9]. The disbudding procedure is usually performed under both general and local anesthesia [10]. Local anesthesia, typically lidocaine, is administered to block the cornual nerve and to provide infiltration around the horn bud. Xylazine (Xylazin Bio 2%, Bioveta, Cluj-Napoca, Romania) is administered to provide sedation and also exhibits analgesic effects. When combined with non-steroidal anti-inflammatory drugs (NSAIDs), it is used to alleviate pain in cattle [11,12]. In thermal disbudding procedures for calves, ensuring both speed and safety for the animals and operators is crucial. Additionally, it is important to effectively manage potential post-operative complications such as tissue necrosis, hemorrhage, bone fracture, meningoencephalitis, sinusitis, or even mortality [2,13].

There are various methods for disbudding in calves, which utilize surgical, chemical, and thermal techniques or a combination of these approaches [6,14,15]. For the hot-iron disbudding procedure, some authors recommend assessing the size of the horn buds rather than the age of the animal [16].

Clinical examination of the burn wound depth is mainly based on visual inspection and provides an accurate prognosis in 50 to 70% of cases [17]. Skin burns are classified as follows: I degree—superficial, IIa degree—superficial dermal, II degree—deep dermal, and III degree—full thickness of the skin [18].

Several studies have investigated the diagnostic role of different types of thermal images in burn wound assessment [19,20]. The findings of these studies suggest that deeply burned skin areas exhibit lower temperatures on thermal images compared to unaffected skin [21]. This temperature decrease in deeply burned skin is primarily attributed to the destruction of the subdermal plexus, although reduced metabolism in injured cells may also contribute to this phenomenon. In contrast to deep burns, superficial burns typically display higher temperatures than unaffected skin [22]. This elevation in temperature may be attributed to factors such as vasodilation, inflammation, edema, and loss of the epidermal layer [9,22]. Easy to handle, small, low-cost, thermal imager devices have become available in burns scanning [23].

Infrared thermography (IRT) is a non-invasive, quantitative assessment of temperature, producing a pictorial representation of the surface temperature of an object [16,17]. IRT can be used as a non-invasive diagnostic method to provide information about local inflammatory processes resulting from surgical procedures, neoplasms, burns, wounds, painful events, stressful states in animals, or even footprints [14,15,17]. IRT could be used to assess blood flow patterns and identify areas with thromboembolic disease and burns [13,14]. This information could aid in early detection between damaged and healthy tissue, thus allowing for determination of the optimal therapy for burn patients [14].

The evolution of the local temperature in deeply burned tissue appears colder on a thermal image than in unaffected skin [20,21]. The temperature decrease in deeply burned skin is primarily caused by the destruction of the subdermal plexus. However, injured cells are less capable of producing heat, which also leads to a decrease in temperature in the burned area [2,16]. On the other hand, superficial burns show higher temperatures than unaffected skin, which may be caused by inflammation, vasodilation, edema, and loss of the epidermal layer [16,18].

Schwartzkopf-Genswein and Stookey, 1997 [21], used thermography for the evaluation of local temperature after the application of a hot-iron or freeze branding to produce a permanently visible mark on cattle. Both procedures led to tissue damage and an increase in local temperatures.

There are no data in the literature referring to the changes in local temperature of the tissue recorded before and after thermal disbudding [22–24]. Additionally, there are no studies in the veterinary literature showing that locally recorded temperature exceeds the value at which tissue necrosis occurs after a hot-iron disbudding procedure [6,10].

The present study aimed to determine whether the maximum and mean values of temperature attain the values required for tissue necrosis, to identify the differences in the thermal pattern of the cornual area before and after disbudding, and to check if thermographic examination can be used to detect changes in the local temperature of the cornual area before and after disbudding.

We hypothesized that the thermal pattern and the local temperature of the horn bud area would not undergo changes in pattern and temperature after the disbudding procedure.

2. Materials and Methods

This study was approved by the Bioethics Commission of Banat University of Agricultural Sciences and Veterinary Medicine “King Michael I of Romania” from Timisoara according to the guidelines of the Declaration of Helsinki, No. 390/26.03.2024.

2.1. Animal Selection

This study was undertaken by the team of the Surgery Clinic in the Experimental Teaching Unit in April of 2024.

A total of 50 one-month-old female Romanian Spotted Cattle calves weighing 55 to 62 kg (mean 59 kg) were included in this study. The calves were scheduled for disbudding according to usual husbandry practice and were clinically examined.

The animals were kept inside a shelter under the same conditions and were grouped in enclosures containing 10 animals each. Inclusion criteria were as follows: female calves, animals without clinical signs of diarrhea, presence of horn buds not attached to the frontal bone, and size of the horn buds between 13–15 mm diameter. The clinical exam was performed by two veterinarians (C.Z. and R.D.) two days prior to the procedure and the morning before the hot-iron disbudding procedure. The rectal temperature was measured, and the results were between 37 °C and 38 °C. The diameter of the horn buds was measured using a caliper, and the mean of the horn bud diameter was 14.21 mm². The exclusion criteria consisted of the presence of symptoms such as coughing or fever, depression, anorexia, size of the horn buds exceeding 13–15 mm, and horn buds attached to the frontal bone.

Out of fifty calves enrolled in this study, 36 were accepted, in correlation with the clinical signs of the animals and confirmation of the inclusion criteria. A total of 11 calves presented with a horn bud exceeding the mentioned limits and 7 calves presented an attachment of a horn bud to the frontal bone.

The calves were sedated with 20 mg/mL of xylazin hydrochloride (Xylazin Bio 2%®, Bioveta, Cluj-Napoca, Romania), administered through IV infusion at a dose of 0.15 mg/kg. All animals were positioned in sternal recumbency, showing signs of full sedation within 5 min [25,26]. After sedation with Xylazin (Xylazin Bio 2%®, Bioveta, Cluj-Napoca, Romania), a quantity of 2 mL of lidocaine hydrochloride 10 mg/mL (Xiline®, Zentiva, Prague, Czechia) was administered subcutaneously around the cornual nerve located along the occipital groove at half distance between the horn bud and the eye [27,28]. A quantity of 4 mL of the same local anesthetic was injected in a circular block shape around each horn bud [11,29].

2.2. Thermal Imaging and Data Recording

We evaluated the intensity of radiation in the infrared spectrum of the horn bud area before the thermal disbudding procedure, five seconds after the procedure, and two hours after the procedure was finished. All the calves were subjected to the same procedures. An area classified as EI1 at a size of 8 × 4 pixels was marked on the thermographic image.

All measurements for each calf were registered by the same operator and complied with similar environmental conditions, i.e., air temperature of 19–21 °C and humidity between 65% and 75%. The Testo 435 (Testo, Titisee-Neustadt, Germany) device was used to measure humidity, air temperature, and air currents. In order to perform the thermal disbudding procedure, the operator restrained the animals by standing over

them and limiting the movements of the neck and head. The hair was clipped on an area of 4 cm² centered on the horn bud one day before the hot-iron disbudding, so the calves did not require an additional acclimatization period. Thermographic images were obtained using a calibrated FLIR E50 (FLIR Systems Inc., Wilsonville, OR, USA) infrared camera with the following parameters: 0.95 emissivity and 240 × 180 resolution for each image. The temperature range was between −20 and 650 °C, and the sensitivity was ≤0.05 °C. To identify the maximum and mean temperatures of the projection, we used FLIR Tools software 1.24.15 for photo interpretation, and the procedure was conducted by a single operator.

Only the left side of each calf was selected for thermographic scanning; the scanning angle to the horn bud area was 90°, and the distance from the camera to the selected area was 1 m.

2.3. Thermal Disbudding Procedure

The treatment for disbudding was conducted over a three-day period and was performed at the same time each day, namely between 8 a.m. and 2 p.m., to avoid any effects on the calves' circadian rhythms. The entire disbudding procedure was carried out by the same operator.

An 18 mm tip hot-iron device, Mains-Powered Dehorer (Kerbl, Buchbach, Germany), was used for thermal disbudding. The device was centered on the horn bud and it was kept in contact for 15 s. The hot-iron device was plugged in 11 min before use to reach the maximum temperature of 620 °C indicated by the manufacturer. The device was applied centered to the horn bud directly on the skin without making rotational movements; only pressure was applied to the skin. After 15 s, the hot-iron device was lifted from the skin and the necrotic tissue was left in position without removal.

All the calves received an intravenous injection of Meloxicam (Melovem®, Dopharma, Ghiroda, Romania), at a dose of 0.5 mg/kilogram at 2 h from disbudding, after the last thermographic image was performed [18,19]. A topical Neo Caf Spray (Intervet, Chiajna, Romania) was applied after the last thermographic scanning until a film of material had formed over the necrotic tissue.

2.4. Statistical Analysis

Comparisons between groups of temperature measurements—namely temperature recordings before dehorning, 5 s after dehorning, and 2 h after dehorning—were statistically performed using the paired *t* test. The chosen significance threshold was $\alpha < 0.05$. The mean value for the maximum temperature represented by a.max.v.t, which was measured prior to and after thermal disbudding, was calculated separately for each thermal scanning, and represented an element for comparison. The mean temperature for the maximum value and the mean temperature for the average value were calculated both before the disbudding and at 5 s and 2 h after the procedure. These values were used for comparison purposes and the result was abbreviated as a.mean.v.t. The SAS Studio software On Demand for Academics was used for the Box-plot diagrams while for comparisons between temperature groups, we utilized the R in JASP software 0.17.1.

3. Results

3.1. Macroscopic Evaluation

The horn bud exhibits slight mobility within the skin and is not connected to the frontal bone (Figure 1a). Following thermal disbudding, a black circular mark measuring 18 mm in diameter forms around the horn bud. The burn extends throughout the epidermis, with III-degree burns occurring at the margins of the hot-iron device (see Figure 1b). The circular area of necrosis to the epidermis, identified as a III-degree burn, corresponds to the application edge of the thermocautery. No hemorrhage was observed after thermal disbudding in any of the calves. The necrotic tissue remained adherent to the substrate for all cases studied.

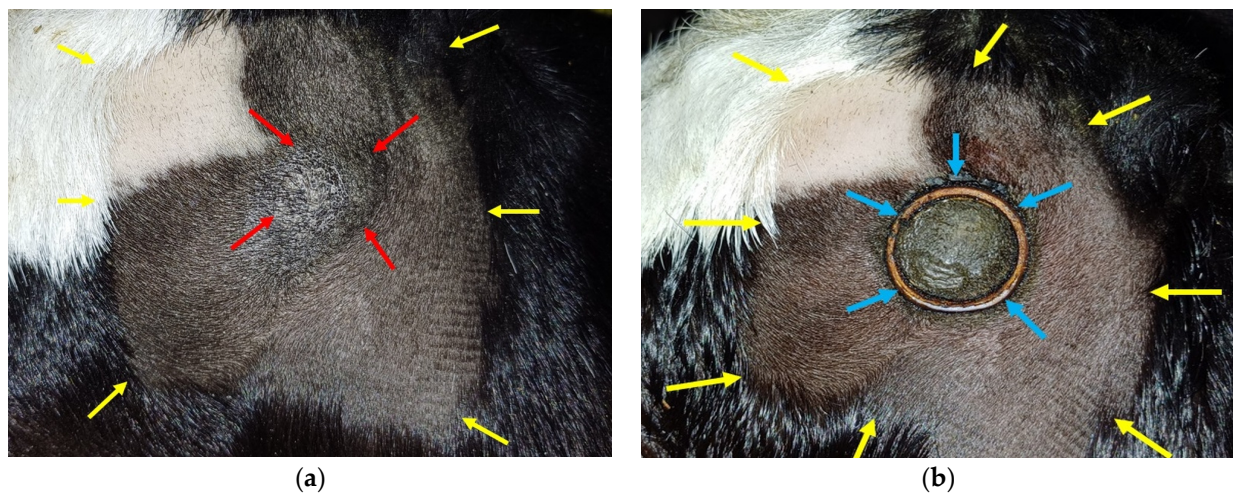


Figure 1. Photo of the horn bud area: (a) image obtained with Samsung A34; (b) image obtained with Samsung A34. Arrows: (a) red arrows—horn bud; yellow arrows—clipped hair area; (b) blue arrows—burned tissue after hot-iron contact for 15 s; and yellow arrows—clipped hair area.

None of the calves showed ear movements, kicking, or head tilting during the hot-iron disbudding procedure.

3.2. Thermographic Scan

3.2.1. Thermography before Thermal Disbudding

The horn bud region shows a mildly colored area compared with the adjacent skin region following thermographic scanning (Figure 2a). The a.mean.v.t. for the horn bud region before dehorning was 34.41 °C, and the a.max.v.t. for the same region was 35.90 °C (Figure 2b).

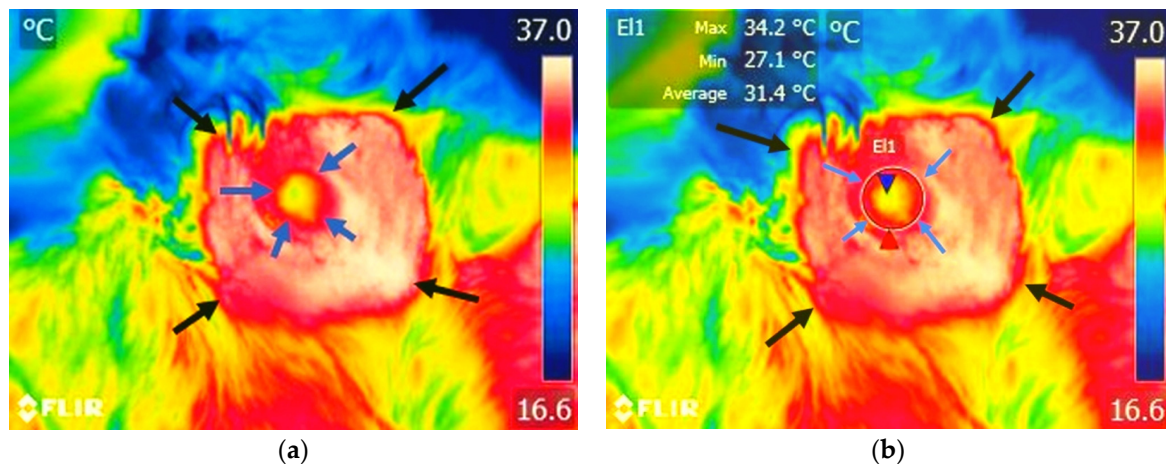


Figure 2. Thermographic images obtained before hot-iron disbudding. (a) Thermographic image without FLIR Tools software analysis: black arrows—clipped hair area; blue arrows—horn bud area. (b) Thermographic image with analysis FLIR Tools software: blue arrows—El1, area of measurement; blue triangle spot—minimum temperature recorded in the interest area; red triangle spot—maximum temperature recorded in the interest area; and black arrows—clipped hair area.

3.2.2. Thermography at 5 s after Thermal Disbudding

The local temperature following thermal cautery application shows a uniform halo with a very high temperature compared with the surrounding tissues; this aspect was identified as a result of thermographic scanning.

The circular region (white arrows) showing increased temperatures corresponds to the site where the hot-iron was applied. Macroscopically, the aspect is consistent with that of burnt tissue (Figure 1b—blue arrows). Between the thermal cautery application area and the skin tissue, a transition zone with a well-defined halo is observed (Figure 3a). The a.mean.v.t. was 92.09 °C and the a.max.v.t. was 136.5 °C (Figure 3b).

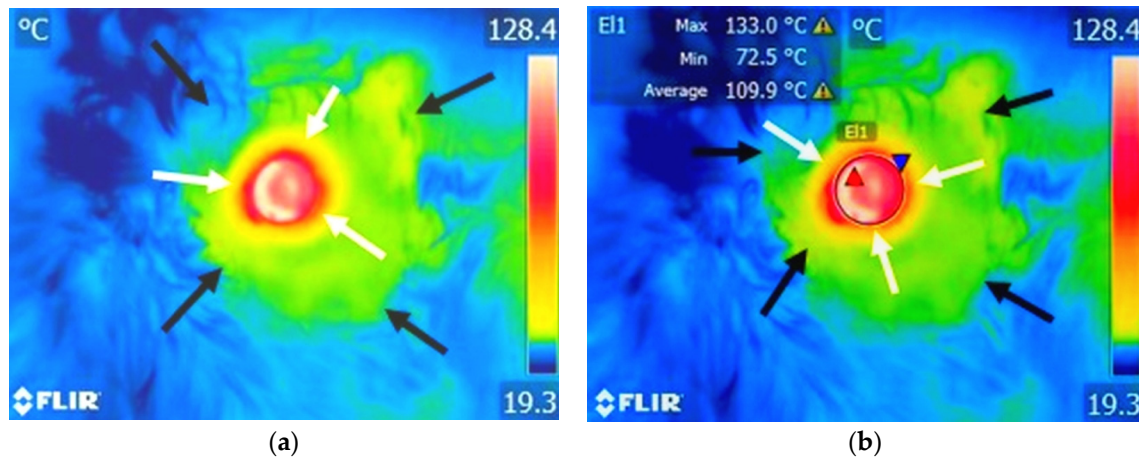


Figure 3. Thermographic images obtained at 5 s after hot-iron disbudding. (a) Thermographic image without FLIR Tools software analysis: black arrows—clipped hair area; white arrows—thermal disbudding area. (b) Thermographic image with FLIR Tools software analysis: black arrows—clipped hair area; white arrows—thermal disbudding area; E1—area of measurement; blue triangle spot—minimum temperature recorded in the interest area; and red triangle spot—maximum temperature recorded in the interest area.

3.2.3. Thermography at 2 h after Thermal Disbudding

Two hours after the application of the thermal cautery, an area of reduced temperature is observed compared with the temperature recorded for adjacent tissues following thermographic scanning (Figure 4a). The local temperature around the area of hot-iron application has not experienced any macroscopic variations in temperature.

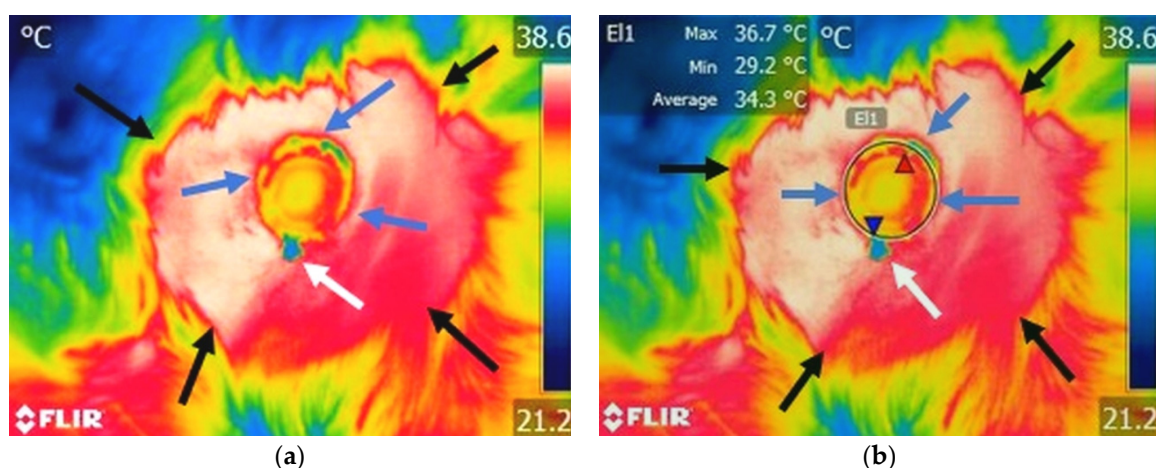


Figure 4. Thermographic images obtained two hours after hot-iron disbudding. (a) Thermographic image without FLIR Tools software analysis: black arrows—clipped hair area; blue arrows—necrotic band area with reduced area of temperature; and white arrows—exudate. (b) Thermographic image with FLIR Tools software analysis: black arrows—clipped hair area; blue arrows—thermal disbudding area; E1—area of measurement; blue triangle spot—minimum temperature recorded in the interest area; and red triangle spot—maximum temperature recorded in the interest area.

The circular area with reduced temperature identified by thermographic scanning (Figure 4a—blue arrows) is associated with the area of tissue necrosis observed macroscopically (Figure 1b—blue arrows). No transition halo between the hot-iron application and surrounding tissue was identified. A small amount of exudate was identified in the area of epidermal necrosis in 12 out of 36 disbudded calves. A.mean.v.t. was 36.96 °C and a.max.v.t. was 38.90 °C (Figure 4b).

3.3. Group Comparisons

Mean and maximum temperatures were calculated for the three temperature measurements: mean temperature values before dehorning, mean temperature values five seconds after dehorning, and mean temperature values two hours after dehorning using the *t*-test.

3.3.1. Group Comparison Mean Temperature before and 2 h after Thermal Disbudding

Following the application of the paired *t* test, by comparing each individual from the group in two stages, it was found that the mean temperature values before disbudding [32.73 °C] differed statistically significantly from the mean temperature values measured at two hours after disbudding [34.75 °C], with a result of $t = -14.4$, $p < 0.001$ (File S1).

The same result followed the application of the paired *t* test; by comparing each individual from the group in two stages, it was found that the maximum temperature values before disbudding [34.41 °C] were significantly from the mean temperature values measured at 2 two hours after disbudding [36.96 °C], resulting in $t = -15.5$, $p < 0.001$ (File S2).

In addition, Box-Plot diagrams show the comparative distribution of mean temperature values between the group of calves before dehorning and two hours after dehorning (Figure 5a) and the distribution of maximum temperature values between the group of calves before dehorning and two hours after dehorning (Figure 5b).

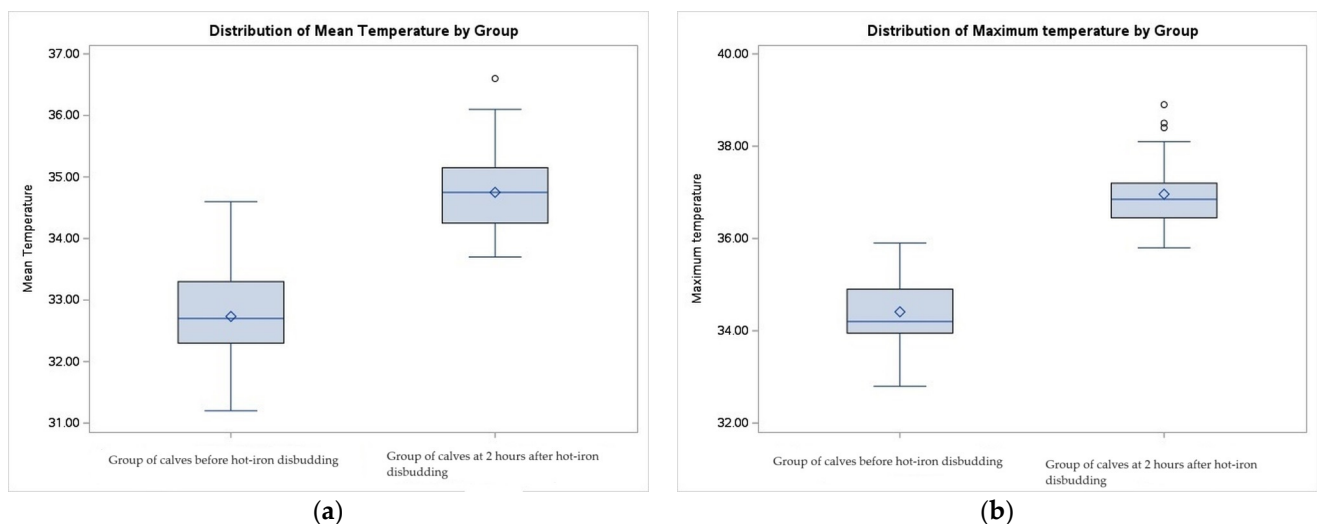


Figure 5. Comparative boxplot referring to results obtained for the group before hot-iron disbudding and two hours after the hot-iron disbudding procedure: (a) distribution of the mean temperature; (b) distribution of the maximum temperature; $\diamond$ —mean referee value; and $\circ$ —outliers.

3.3.2. Group Comparison Maximum Temperature before and at 5 s after Thermal Disbudding

Comparisons between mean temperature values recorded before dehorning and five seconds after dehorning differed statistically significantly following the application of the paired *t* test, with a result of $t = -96.48$, $p < 0.001$, with mean temperature before dehorning [32.73 °C] and a mean temperature at five seconds after dehorning [103.18 °C] (File S3).

Following the application of the paired t test, by comparing each individual from the group in two stages, it was found that the maximum temperature values before disbudding [34.41 °C] differed statistically significantly from the maximum temperature values measured at five seconds after disbudding [126.5 °C], with a result of $t = -61.38$, $p < 0.001$, indicating a difference over 90 °C (File S4).

In addition, the Box-Plot diagrams show the comparative distribution of mean temperature values between the group of calves before dehorning and at five seconds after dehorning (Figure 6a) and the distribution of maximum temperature values between the group of calves before dehorning and at five seconds after dehorning (Figure 6b).

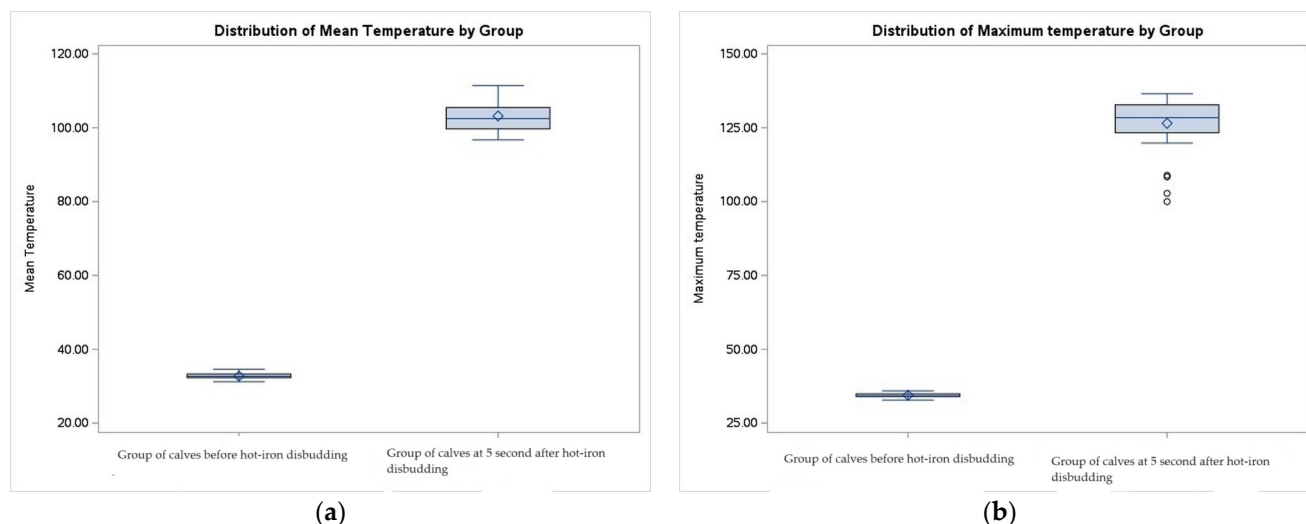


Figure 6. Comparative boxplot referring to results obtained for the group before hot-iron disbudding and five seconds after hot-iron disbudding: (a) distribution of the mean temperature; (b) distribution for the maximum temperature; $\diamond$ —mean referee value; and $\circ$ —outliers.

4. Discussion

Thermography of the horn bud area before and after thermal disbudding allowed us to identify changes in local temperature and thermal pattern. This observation is highlighted by the rejection of the null hypothesis regarding local temperature and the thermal pattern after the disbudding procedure. The thermal pattern of the horn bud area after thermal disbudding presents changes and the local temperature undergoes a significant increase in temperature.

According to Asif et al., 2022 [30], thermography is a feasible method for assessing burn depth, as was observed in a study that investigated the accuracy of IRT for wound depth assessment.

In our study, the mean temperature of the local area at 5 s after thermal disbudding exceeded 70 °C, while observations regarding tissue burns carried out by Martin and Falder state that the rate of injury exceeds cellular adaptation, meaning that less than 1 s at 44 °C is required for transepidermal necrosis to occur [8,31].

Two hours after the thermal disbudding procedure, the local temperature of the horn buds decreased by up to 60% compared with the temperature 5 s after the procedure. In a study conducted by Schref et al., 2020 [32], their results showed that 30 min after thermal disbudding, the local temperature decreased by up to 50%.

After dehorning, in the region of the horn bud, a circular area with reduced temperature is observed, compared with the adjacent areas, indicating the destruction of the local circulation. Heinrich et al., 2010 [13], and Paul et al., 2015 [27], identified similar observations for burn injuries due to local microcirculation destruction.

The burned tissue is associated with the area where the hot iron was applied. During thermal scanning, it was identified as a region with lower temperature, thus demonstrating that thermography allows for discrimination between superficial and deep burns [23].

According to Romero-Mendez, R., 2009 [18], thermography scanning may be used as a non-invasive method for estimating the depth of burn through measuring the temperature differences between the burned skin and the unaffected reference area [18]. Thermographic images were used in human studies to measure tissue damage, and the authors revealed that superficial burns appear warmer than uninjured skin due to inflammation compared with deeper burns that are cooler due to vascular damage [21,33]. In our study, the burn was classified as a III-degree burn wound, affecting the full thickness of the skin.

No local hemorrhage following thermal disbudding was observed in our study, which is similar to observations reported by other authors [25,34]. This fact is due to vascular cauterization consequent to high temperatures [35].

Exudate is a liquid produced by the body in response to tissue injury and can provide information about wound healing [28,29,36]. In our study, a small amount of exudate was identified in 12 out of the 36 disbudded calves.

In our study, the disbudding procedures were performed on four-week-old calves using a hot-iron device using methods similar to those provided by other authors [1,37].

To obtain a good thermographic image, the animals must have dry skin, without visible moisture; moreover, the animals must not have received any physical therapy within the past 24 h [33]. The local anesthetic can influence the local skin temperature as a result of the temperature of the solution [38]. For our study, the local anesthetic solution was kept at the same temperature to avoid any possible differences between calves.

The combination of general anesthesia with Xylazin (Xylazin Bio 2%[®], Bioveta, Cluj-Napoca, Romania) and local blockage of the cornual nerve and the ring block around the horn bud demonstrated a good effect without any behavioral responses, such as kicking or head lifting, during the hot-iron disbudding procedure [28,31].

The use of a cornual nerve block and a ring block in our study appeared to be effective for the control of acute pain. In similar studies, authors reported the observation of increased respiratory and heart rates after both anesthetic procedures [34–36].

The temperature in the shelter was maintained between 20–21 °C; this temperature has been recommended in other studies in order to avoid influencing the body temperatures of the animals during thermography [33,38].

In our study, a solution of Meloxicam (Melovem[®], Dopharma) was administered to ensure post-procedural analgesia [39], which is a product that has been used in other studies for pain management after the disbudding procedure [40,41].

This study has some limitations; first, we mention that the camera resolution was quite low at 240 × 180 pixels with 0.95 emissivity. For further studies, we propose the use of a higher resolution camera of 640 × 480 pixels. Another limitation of this study is the follow-up period in measuring the evolution of the local temperature. A solution to this limitation in further investigations would be a longer period of time dedicated to the verification of local temperature during the healing period of the affected area. Moreover, the duration of contact between the hot-iron device and the horn bud area can be a limitation of this study. Therefore, in future investigations, we will endeavor to conduct a comparison between different periods of time (i.e., 10 s, 15 s, and 20 s) followed by a longer observation of the healing process and the possible re-growth of the horn.

5. Conclusions

The results of this study showed that differences exist in both the local temperature and thermal pattern of horn buds following hot-iron disbudding. The average temperature recorded via thermography after hot-iron disbudding surpassed the threshold for epidermal tissue necrosis. Based on the findings of this initial study, we affirm that a 15 s application of the hot-iron device induces tissue necrosis.

The thermographic scanning effectively distinguishes the necrotic tissue and temperatures changes induced after hot-iron disbudding from adjacent healthy tissue.

Thermographic investigation discriminates the superficial burns from deep burns through the fact that the local tissue reaction following a hot-iron disbudding procedure is similar to that observed in third-degree burn wounds. Thermographic evaluations help us to effectively discriminate between superficial burns and deep burns such as those induced by hot-iron disbudding.

Further research is required to assess local healing over an extended period after hot-iron disbudding, as well as to characterize the thermal patterns at each stage of healing.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/agriculture14071019/s1>, File S1. Paired *t* test result for mean temperature before and after two hours from disbudding; File S2. Paired *t* test result for maximum temperature before and after two hours from disbudding; File S3. Paired *t* test result for mean temperature before and after five seconds from disbudding; File S4. Paired *t* test result for maximum temperature before and after five seconds from disbudding.

Author Contributions: Methodology and study supervision, conceptualization, C.I. and C.Z.; manuscript preparation, data collection, original draft preparation, design, and writing, C.Z.; data collection and investigation, P.N., R.D., L.S. and T.F.; acquisition of data and manuscript review, T.F. and A.P.; and statistical analysis and interpretation of data, C.R. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki, No. 390/26.03.2024, and approved by the Bioethics Commission of Banat University of Agricultural Sciences and Veterinary Medicine “King Michael I of Romania” from Timisoara.

Data Availability Statement: All the data obtained for this preliminary study are available in the Clinical Register of Large Animals of the Surgery Clinic.

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Conflicts of Interest: The authors declare no conflicts of interest.

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