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Hot Iron Branding of Beef Cattle: Process Characterization, Implications for Animal Welfare, and Its Efficiency for Cattle Individual Identification

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Abstract: This study aimed to characterize the hot iron branding (HIB) procedure by assessing its implications for animal welfare and its efficiency for cattle identification. The study was carried out in two stages: First, with 37 Nellore calves, by measuring the skin temperatures in the place of HIB application (ONB) and 10 cm above it (OFFB) immediately after its application and during four consecutive days, the time required for application of each HIB digit and the occurrences of rebranding; second, with two batches of cows (N = 97 and N = 94, respectively, by measuring the time spent to read cattle ID and comparing the efficiency of HIB vs. EET (electronic ear tag) and visual ear tags (VET) vs. EET. Skin temperature was significantly affected by the interaction between the place where the skin temperatures were taken (on and 10 cm above the HIB) and assessment day, with temperatures in ONB on days d0 and d2 being higher than in OFFB ($p < 0.05$), and 86% of the calves required at least one rebranding. EET reading was faster than HIB and VET ($p < 0.001$), and fewer errors were made when reading EET than HIB (1/97 vs. 17/97) and VET (2/94 vs. 12/94). We concluded that HIB potentially compromises cattle welfare and has a lower efficiency for cattle identification than EET and VET.

Keywords: electronic ear tag; handling; inflammation; skin temperature; visual ear tag

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1. Introduction

Animal identification is essential for ownership, herd management, cattle health control and trade. Moreover, identifying animals properly is essential for food safety, genetic evaluation and cattle traceability, identification of health issues and treatments and, consequently, the safety of the products that originate from livestock species [1].

HIB results in a permanent skin mark, a product of a second or third-degree burn on the hide of an animal with a hot iron [2]. The burns resulting from hot iron branding are followed by immediate behavioral changes related to acute pain [3,4]. Moreover, long-term physiological responses are observed, such as the installation of an inflammatory process

that lasts for at least 71 days, being the complete healing process identified only 8 weeks after the branding procedure [5].

Besides the negative effect on the animals, cattle handling for hot iron branding also represents a risk for workers [6] due to the discomfort caused by the smoke resulting from the burning of the animal's hair and skin. Moreover, human well-being is compromised by the extra heat and noise generated by the propane branding iron heaters, with an associated increase in the risk of labor accidents.

In addition to the impacts on human and animal welfare, cattle identification with hot iron brands can harm human–animal relationships due to the association made by cattle between humans and the feelings of pain, discomfort, and/or fear [7]. On the other hand, when adopting less threatening and painful handling practices, the likelihood of cattle showing high reactivity when interacting with humans is reduced [8], which facilitates work and reduces the risk of labor accidents. Therefore, minimizing negative human-animal interactions is an essential strategy to improve overall welfare, as well as it is an economically advantageous approach [7].

Despite all these disadvantages, hot iron branding is still widely used to identify cattle in Brazil and many other countries, and in some cases, it is mandatory, as occurs in Brazil with heifer calves vaccinated against brucellosis [9] and, for pedigree cattle registration in most of the Brazilian beef cattle breeders associations [10]. This probably happens due to its strong tradition raised from a long history of using HIB for livestock identification and its assumed low cost. One could expect that the development of new technologies for cattle identification would break the resistance to ceasing the use of hot iron branding. Nevertheless, this was not the case. In addition, the technological alternatives did not stimulate the development of comparative studies to evaluate the efficiency of hot iron branding for cattle individual identification. Thus, this study aimed to characterize the hot iron branding procedure, evaluate its impact on animal welfare and assess its efficiency for individual identification of Nellore cattle.

2. Materials and Methods

The Committee of Ethical Use of Animals of the Faculty of Agricultural and Veterinary Sciences, São Paulo State University, Jaboticabal, SP, Brazil, approved the study (Protocol n. 085668/19). It is important to highlight that the application of hot iron brands followed the guidelines of the Brazilian Association of Zebu Breeders [10].

2.1. Hot Iron Branding (HIB) Process Characterization

To characterize the hot iron branding process, the first stage of the present study was carried out in a commercial farm located in the municipality of Barra do Garças, State of Mato Grosso, Brazil. Data collection was performed between 24 November and 1 December 2020, following the hot iron branding handling procedures of 37 recently weaned Nellore calves (~8 months of age), weighing 220 kg on average.

The management procedure started driving the animals from the pasture to the corral facility always in the morning, around 8 a.m. It was performed slowly by three cowhands on horseback, covering a distance of approximately 300 m. When processed, each animal was restrained in a squeeze chute (Beckhauser® Manejo Racional e Produtivo, Maringá, PR, Brazil) for the branding procedure. After the restraint of each calf in the squeeze chute, eight digits were branded on the dorsal part of the right hind leg of each calf, resulting in a combination of four letters, which correspond to the breeder's identification acronym, and four numbers (positioned immediately below the letters), which correspond to the individual identification of each animal. It is important to highlight that a single well-trained veterinarian applied the hot iron brands using stainless steel irons heated in two propane branding iron heaters.

The animal's skin temperature (measured using a CATS60 FLIR thermal camera, Caterpillar Inc., Bullit Mobile Ltd., Oxford, England), the time spent applying each hot iron brand and the need for rebranding were recorded to characterize the branding process.

Thermal photographs were taken at the site of application of the first letter of the brand (ONB), positioned on the upper part of the right hind limb [10] and 10 cm above it (OFFB), being taken a few seconds after the first application of the iron brand, and repeated for four consecutive days. The definition of these locations considered the practicality of taking measurements without disturbing the process of marking the hot iron. Air temperature and exposure to solar radiation affect skin temperature [11]. Calves were kept in a shaded area before the hot iron brand application; there was no rain, and the air temperature was similar throughout the data collection days. Therefore, we did not adjust the skin temperature records. The time spent applying each brand was recorded with a chronometer, starting when the veterinarian responsible for branding removed the iron from the heater and stopped when repositioning them back to the heater for reheating. Occurrences of reapplication of the brand (rebranding) were recorded every time the veterinarian deemed it necessary to redo it, ensuring a good visualization of all letters and numbers.

2.2. Efficiency of the Identification Methods

To determine the efficiency of the identification method, hot iron branding for animal identification (HIB) and identification through the identification of visual ear tags (VETs) were compared to radiofrequency electronic ear tags (EETs); in this case, the readability with the identification of the animal obtained by using the EET (HDX Reusable EID Tag, Allflex Livestock Intelligence® Brazil, Joinvile, SC, Brazil) was the reference method, and there was no comparison with visual reading methods (HIB and VET).

The assessments were carried out from 11 October 2021 to 13 October 2021 on a commercial beef cattle farm located in the municipality of Araguaiana, State of Mato Grosso, Brazil, which has a cow-calf operation with Nellore cows and pure and crossbred calves (Nellore and Angus x Nellore). During the routine handling procedure for weighing cows, the visual legibility of the HIB and VET were evaluated in two batches of cows compared to EET (HIB vs. EET1, N = 97 cows and VET vs. EET2, 94 cows).

To this end, data collection involved three people: two veterinarians and a cowhand. The cowhand, who usually works during this handling routine, read the visual individual identification number out loud, and one of the veterinarians recorded the number, while the other followed the identification registered on the computer after EET reading (reader RS420 Stick Reader, Allflex Livestock Intelligence® Brazil, Joinvile, SC, Brazil) the EET. Therefore, the reference for evaluating the readability efficiency of HIB and VET was the EET.

The assessments were carried out considering the following variables: (1) time spent to identify each of the cows, which was measured from the time the cow entered the squeeze chute until the information was recorded on the computer (EET) and on a sheet (HIB and VET); (2) failure to identify the cow when reading the HIB and the VET (wrong numbers or loss of the VET); and (3) failure to identify with the EET (failure to read or loss of the EET).

2.3. Statistical Analysis

Statistical analyses were performed in the R software with the RStudio integrated development environment (R version 4.1.3 (10 March 2022, RStudio, Inc., Boston, MA, USA). All data were subjected to normality tests by implementing the Shapiro-Wilk test and the homoscedasticity of variances by Levene's test. When the residuals of the variables did not meet the assumptions, non-parametric tests were used. In all statistical tests, significant differences were considered when $p < 0.05$.

For the comparisons between skin temperatures taken ONB and OFFB, the Wilcoxon test was used. Furthermore, the Kruskal–Wallis (KW) test adjusted with the Bonferroni correction was used to compare ONB and OFFB skin temperatures throughout the assessment days. Dunn's test for multiple comparisons was used as a post-hoc test. The rebranding occurrences were described by using absolute and relative frequencies, and to evaluate readability and compare the three identification methods, the time spent reading

the identification number of each animal and the rates of failure or errors when doing this procedure were evaluated using the Student's *t*-test and Fisher's exact test, respectively.

3. Results

3.1. Hot Iron Branding Process Characterization

ONB and OFFB skin temperatures differed significantly (Wilcoxon test = 15,364; $p < 0.001$; Figure 1a), and there was an interaction between the place where skin temperature was measured (ONB and OFFB) and the day of assessment (KWdf = 9 = 227.36; $p < 0.001$), with the median temperatures ONB and OFFB on d0 being 50.60 °C (ranging from 39.40 to 59.70 °C) and 34.3 °C (ranging from 32.70 to 36.60 °C), respectively ($p < 0.05$; Figure 1b). On d2, ONB and OFFB temperatures were 36.1 °C (ranging from 34.80 to 37.70 °C) and 34.8 °C (ranging from 33.30 to 36.20 °C), respectively ($p < 0.05$; Figure 1b).

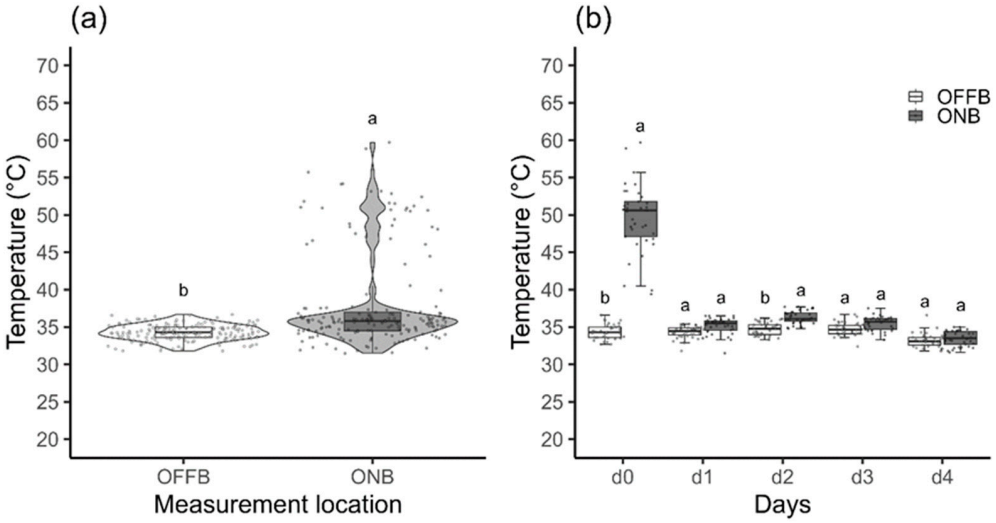

Figure 1. (**a**) Violin plot of the skin temperatures on (ONB) and off (OFFB) the hot iron brands and (**b**) box plot of the skin temperatures ONB and OFFB according to the day of the assessments. The width of the violin represents data distribution, indicating individual variation. The upper and lower lines in the box plots represent the interquartile range (25 to 75%). The black line indicates the median. Different letters indicate statistical differences ($p < 0.05$) between hot iron brand locations (a) and days (b).

The average time needed to apply the hot iron brand in each animal was 73.19 ± 9.84 s. The total handling period monitored in this study was approximately 4 h, and of the 37 hot iron branded calves, 32 (86%) received at least one rebranding among the eight digits branded on the dorsal part of the right hind leg of the calf.

3.2. The Efficiency of Identification Methods

The time needed to read the EET identification number was significantly shorter than the time required to read the HIB (t = −12.94; $p < 0.001$) and the VET (t = −8.44; $p < 0.001$), as shown in Table 1.

The percentage of error in reading the cows' identification in the EET was 1.03% (1/97, a lost tag), while for the HIB, the error was 17.53% (17/97), ($p < 0.001$, Figure 2), and the percentages of errors in the EET and VET were 2.13% (2/94, two lost tags) and 12.77% (12/94, including three VETs lost), respectively ($p = 0.005$; Figure 2).

Table 1. Summary statistics for the time (in seconds) required to read the identification number of each cow according to the identification method, where HIB = hot iron brand, EET = electronic ear tag and VET = visual ear tag. Different letters indicate statistical differences ($p < 0.05$).

	N	Mean	SD	Min.	Max.
HIB	97	7.97 [a]	2.33	4.00	21.00
EET	96	4.34 [b]	1.34	1.00	9.00
VET	91	8.90 [a]	2.58	5.00	19.00
EET	92	5.15 [b]	1.53	3.00	10.00

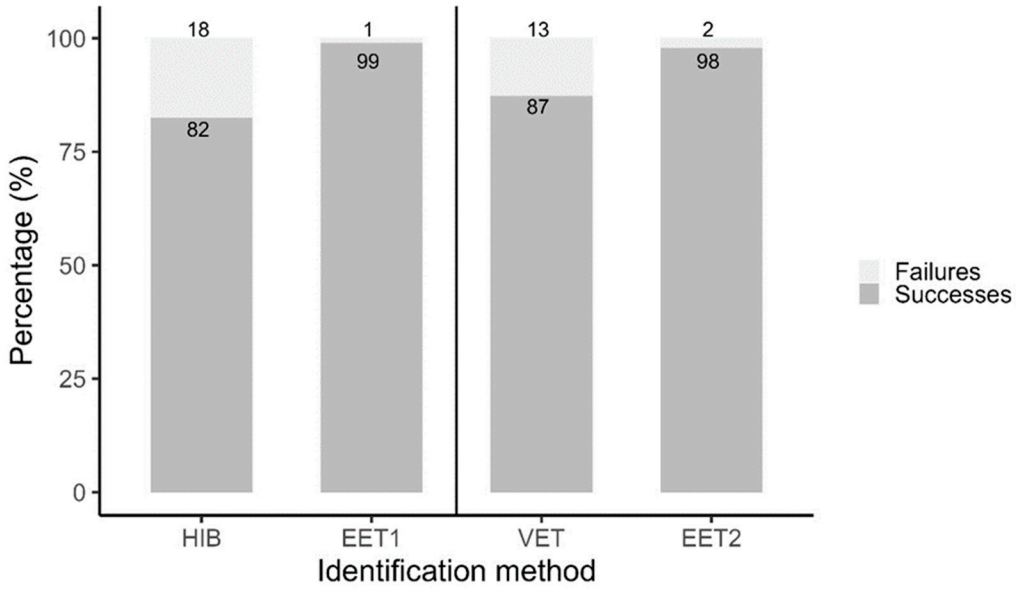

Figure 2. Rates of failures and successes in identifying animals according to the identification method (HIB = hot iron brand vs. EET1 = electronic ear tag in cows from batch 1, and VET = visual ear tag vs. EET2 = electronic ear tag in cows from batch 2).

4. Discussion

Skin temperature is often used to assess the inflammatory process after a nociceptive stimulus [12,13]. Our results corroborated this partially, showing that HIB results in an acute inflammatory process, as characterized by the higher ONB skin temperature on d2 compared to OFFB, but this is not in agreement with the results reported by Tolleson and Schafer [14], who reported that the initial phase of an inflammatory process lasts from 1 to 3 days and the proliferative phase from the 4th to the 21st day, and we did not find significant differences between the ONB and OFFB skin temperatures on d1 and d3. On the other hand, the skin temperatures of some calves on d0 grew close to 60 °C shortly after applying the hot iron branding, which is consistent with Schwartzkopf-Genswein et al. [4] results, showing the highest skin temperature on HIB (close to 45 °C) was recorded just after the HIB application (d0).

Previous studies indicate that pain lasts longer than the inflammatory phase, being extended to the proliferation phase healing process. According to Tucker et al. [5], calves branded with a hot iron remained responsive to wound palpation on the majority of hot iron brands (67%), with the healing process lasting more than ten weeks. Moreover, wound temperature has also been associated with the inflammatory phase in hot iron-disbudded goats, remaining hotter than the temperature of other tissue types over time as the wound heals [15].

A study carried out with horses evaluating the inflammation process associated with hot iron branding reported differences in skin temperature for a longer time than that indicated in the other studies regarding inflammation. The skin temperature was significantly

higher (1.43 °C) in the branded area compared with the nonbranded contralateral control area [16]. The authors highlighted that the differences in skin temperature between the hot iron branded and no-branded areas appeared 24 h after applying the brand and lasted for seven days. Such results differ from ours, which indicated that after three days of the acute phase, signs of inflammation may remain more tenuous.

In our study, no additional problems related to burns were observed, such as the presence of neoplasms in burn scars, which generally occurs in deep, extensive and slow-healing wounds that remain irritated for long periods, which occurs with a greater risk in animals that had the hot iron brand applied inappropriately, such as when animals with wet hair coat are hot iron branded [17].

The use of anesthetics is not a reality in routine management on Brazilian beef cattle farms, so the practice of hot iron branding, among others, negatively affects animal welfare, compromising aspects of the physical domains of health and behavior and, consequently, the mental domain [18]. Besides being painful and the limited effect of pain control on reducing it [6], HIB can also be unpleasant for the people involved in its management [19]. Such conditions, combined with the low efficiency in reading the hot iron mark and the longer time spent reading and transcribing cattle identification to the farm database, lead us to recommend reducing its use.

Eighty-six percent of the calves were rebranded at least once. Such a situation has a direct negative effect on the welfare of the animals and labor efficiency. It is important to emphasize that a high rate of rebranding may result from different factors, such as poorly restrained animals, inexperience or physical and mental fatigue of those applying the hot iron brand, and the conditions of the iron brands used [20]. However, in the present study, the rebranding had a more cautious nature in making a clear animal identification. To the best of our knowledge, no studies are available in the scientific literature characterizing or evaluating the time required to apply the hot iron brands. Thus, our study is the first to show the efficiency of the process under routine management procedures in a commercial beef cattle farm.

Regarding the animal identification efficiency, it was observed that the identification method directly influenced the efficiency of animal identification, with the HIB and the VET being the methods that require more time to read when compared to the EET. A similar result was found by Lopes et al. [21], who evaluated the use of cattle identification methods approved by the Brazilian bovine traceability system [22] and reported that the VET and EET had the shortest time for implementation when compared to HIB and tattooing; and that the time spent for reading the numbers on animals and transcribing them into a database was faster for EET, followed by VET, HIB and tattooing in most of the animal categories evaluated (calves, young and adult cattle).

There was a loss of EET in just two cows, and twelve of them lost the VET, preventing the proper cow individual identification. In both cases, it was necessary to use the ear tattoo to identify each animal, which makes ear tattooing (when performed well) a good alternative in cases of loss of the EET and VET or EET reading failure. The visual methods (HIB and VET) showed lower readability, with more failures in reading the cow identification number than the EET. Due to this, they require more time to identify each animal. The loss or failure of reading the EET was significantly lower (1.03% and 2.13%, respectively) than the HIB (17.53%) and the VET (12.77%). The VET is one of the most used methods to identify beef and dairy cattle, and when looking for better efficiency, its application should be carried out with care and attention since its retention and readability depend on the quality of the tag used and the correct application technique [20].

We did not find any study comparing the efficiency of cattle identification methods. In a study with pigs, Santamarina et al. [23] compared the efficiency of visual and electronic ear tags when assessing identification in a slaughterhouse. The authors found that less than 1% of the EET failed at the time of the final reading in the slaughter line, indicating that besides being more efficient and having good reliability, it is also a technology that is

resistant from farm to the stages of the slaughter line, being recommended for traceability programs, which corresponds with our results.

In a cost analysis, as the number of animals increases, the economic viability of indicators of using electronic identification improves considerably, justifying investment in this technology [21] since the time reading and transcribing cattle individual numbers them into a database when using HIB and VET for cattle identification increases systematically the working hours (considering all the handling procedures in which the individual identification of cattle is needed, for example, during weighing, breeding procedures, and health care), which increases the total annual labor costs.

Although often used, hot iron branding is not the best identification method for cattle as it does not provide sufficient accuracy or reliability, as demonstrated by our results showing an ~18% error in cows' identification, besides impoverishing animal welfare and the image of the beef cattle production chain. In this context, the adoption of animal identification methods that are efficient and reliable, such as electronic ear tags [1], is essential in cattle breeding programs, as through it, the farmers can ensure that the animals being sold or monitored are, in fact, the same animals throughout the production cycle [24]. By this, it is possible to allow the association and tracking of characteristics relevant to an individual [25]. An argument often used to justify using HIB is the ease of reading animals' IDs from a distance, mainly when they are on pasture or in a feedlot pen. However, as reading errors with animals restrained in the squeeze chute reached close to 18%, this value probably will be even higher when reading the number from a distance.

Furthermore, the profile of consumers and the market itself has changed over the years, showing more concern about product quality and animal welfare [19]. From this point on, identification methods less harmful than hot iron branding should be chosen, such as electronic and visual ear tags and tattoos. The American Veterinary Medical Association, AVMA [26] stated that "…while hot-iron branding currently plays an integral role in disease control, it is also recognized as less welfare friendly than other forms of identification…" like ear tagging and tattooing, for example, and despite having some amount of pain associated with their use, this pain is believed to be less than that experienced by hot iron branded animals [26]. We did not find any experiment comparing the pain inflicted by HIB, ear tagging and tattooing that supports such a statement, but in an intuitive approach, we concluded that due to the severity and extension provoked by HIB burns, it results in more intense acute and inflammatory pain than ear tagging and tattooing.

An argument often used to justify the HIB is the possibility of reading the cattle' IDs from a distance when animals are kept on pasture or in feedlot pens. However, when we consider that the error in identifying animals was up to 18% when restrained in the squeeze chute (where it is much easier to read the numbers), this error will likely increase even further, which is unacceptable when expecting to have good herd control. Thus, this is a failed argument even when considering EET or VT for cattle identification will not solve the problem since they also require getting close to the animals to have precise individual identification.

Given the economic, social, and cultural importance that the beef cattle productive chain has in many countries, the search for sustainable production systems that increasingly meet the concept of animal welfare, it is essential to seek or develop animal welfare-friendly methods for cattle identification to reduce the use of hot iron branding.

5. Conclusions

Hot iron branding, besides being an acute painful stimulus at the time it is performed, also triggers an inflammatory process, causing a persistent painful process that persists in the following days, impoverishing the welfare of animals. Furthermore, hot iron branding has proven to be an inefficient identification method compared to electronic ear tags, which may harm the reliability of information in reproductive management and animal breeding programs. Therefore, using electronic ear tags combined with other less painful

identification methods, such as tattooing and visual ear tags, offers the possibility of replacing hot iron branding successfully and permanently.

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