***Original Research Article***

**Performance Evaluation of Stainless Steel and Brass Metal for Freeze Branding in Sahiwal Cattle**

**ABSTRACT**

The present study was conducted on 40 Sahiwal cattle of varying age groups (birth to 12 months) at the Bull Mother Experimental Farm, College of Veterinary Science and A.H., Anjora, Durg, with the animals divided into two groups of 20 each. In the 0–6 month age group, oedema developed more quickly at 9 and 11 seconds of exposure showing a significant difference (P<0.01) when using stainless steel. For brass metal, oedema persistency at 9 seconds of exposure was significantly different (P<0.05), while in stainless steel, exposure times of 7 and 9 seconds differed significantly (P<0.01). In brass metal, exposure times of 7 and 9 seconds differed significantly (P<0.05) for scab formation and its persistency, whereas in stainless steel, 11 seconds of exposure differed significantly (P<0.01). A shorter time was observed for the appearance of white hairs at 5 and 9 seconds using stainless steel, and 100 percent legibility was seen at 7 seconds of exposure using stainless steel. In the 6–12 month age group, the onset of oedema at 8, 11, and 14 seconds in brass metal was significantly different (P<0.05). For stainless steel, the number of days required for skin dryness at 8 and 11 seconds differed significantly (P<0.05), while for brass metal, the 17 second exposure time differed significantly (P<0.05). In both metals, skin dryness occurred significantly (P<0.05) faster at shorter exposure times. In brass metal, a significant difference (P<0.05) was observed between the time required for scab formation and its persistency at 11 and 17 seconds of exposure. A relatively shorter time was required for white hair appearance at 8 to 11 seconds using both metals, and all the brands used could be recommended with an exposure time ranging from 8 to 11 seconds.

**Keywords:** Sahiwal, freeze branding, white hairs, stainless steel, brass

**1. INTRODUCTION**

The identification system is essential for all domestic species. Identification of animals in a livestock enterprise is crucial for assessing their production status and overall performance. Individual animal identification will allow producers to keep records of an animal’s parentage, birth rate, production records, health history, to keep a watch on animals expected to be in heat on a given day, to dry off, to cull, to perform AI and contributes to genetic improvement programs and many more information required to study status of farm (Nandanwar et al., 2017). Proper identification of animals is a key of record keeping leading to improve management of a herd. The majority of cattle and buffalo populations are still raised in an unorganized manner, with only a small percentage managed in organized herds. In both cases, identification procedures remain underdeveloped, creating management challenges and hindering the maintenance of breeding records in breed improvement programs.

Animal identification is an essential aspect of livestock management, involving the assignment of unique markers or identifiers to individual animals. Cattle identification markings should be easy to read from a distance, simple to apply, permanent, durable, and cost-effective. Several methods are currently used to identify animals, though none are entirely flawless or foolproof (Nandanwar et al., 2015 and Mishra et al., 2005). Out of that ear notching is most offenly used in marking pigs. Another commonly used identification method across all species is ear tagging. Ear tags are easy to apply, adaptable to various weather conditions, and relatively inexpensive, making them the primary choice for initial identification in new dairy operations. However, their effectiveness is compromised as they can become smeared with mud and manure, reducing readability. The tattoos cannot be read without catching the head of animal (Hall *et al*., 2004) and is a biggest disadvantage of this method. Neck chains, paint mark and photographs are another temporary method used for short term marking of livestock species. Despite limitations in other methods, hot branding is widely used in both organized and unorganized herds in India. However, it is strongly condemned by animal welfare organizations. This method creates a permanent mark but is extremely painful. Over time, hair growth can obscure the scar, requiring repeated branding. Electronic identification is a promising solution, but its high cost limits adoption. Implementing it in rural areas or under field conditions remains a challenge. Freeze branding is a widely accepted livestock identification method, especially in developed countries, as it is less stressful for animals (Lay et al., 1990). It is commonly used for marking large mammals (Farrell et al., 1978; Newton, 1978). An ideal identification method should cause minimal pain, little to no skin damage, and create a permanent, legible mark visible from 30 feet (Farrell, 1966). The Sahiwal, one of India's best dairy breeds, has a red coat, making any white marks or hair on its skin permanent for life and easily readable from distance.

**2. MATERIALS AND METHODS**

**2.1 Location and Place of Work**

The Bull Mother Experimental Farm, Anjora, Durg, is located at an elevation of 317 meters above mean sea level, with coordinates 21.11° latitude and 81.17° longitude. During summer, the maximum temperature rises to 45°C, while in winter, it drops to 10°C. The average annual rainfall is approximately 1071.16 mm.

**2.2 Selection of Animals**

The present study was conducted on 40 Sahiwal cattle of different age groups. The cattle were divided into two groups, each consisting of 20 animals (Table 1). Their ages ranged from birth to 6–12 months (Hall et al., 2004).

**2.3** **Method of Freeze Branding**

Branding metals, such as stainless steel and brass, are essential instruments that facilitate the transfer of the required temperature to the animal's skin. While previous studies (Farrel et al., 1966 and Whitter et al., 1993) have assessed copper as a branding material, the present study focuses on comparing freeze branding using stainless steel and brass. The metals were molded into an "I" shape, with the width and depth (face to back) of the branding instrument remaining the same for all age groups. However, the length and weight varied according to the age group of the animals (Bath et al., 1981). Liquid nitrogen was used as a refrigerant, maintaining a temperature of approximately -196°C while remaining in a liquid state (Key et al., 1977; Wagner et al., 2000). The frosted branding metal was quickly applied to the cattle's skin with firm pressure, ensuring it remained in place without slipping. Freeze branding experiments have primarily been conducted on exotic breeds, with no documented evidence for indigenous breeds such as Sahiwal. Additionally, there is no established data on the appropriate exposure time for freeze branding in Sahiwal cattle (Table 1). Therefore, this study aimed to observe the series of events after freeze branding thawing of skin, development of oedema, persistency of oedema, dryness of skin, scab formation and its persistency, appearance of white hairs and legibility of white hairs and develop a scoring system for selecting the most suitable metal at different exposure times across various age groups.

**Table 1 Different exposure time proposed for different age group**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Age**  **( months)** | **No. of Animal** | | **Exposure Time (seconds)** | | |
| **Copper** | **Stainless Steel** | **Brass** |
| 0-6 | 20 | 5 | 5 | 5 | 5 |
| 5 | 7 | 7 | 7 |
| 5 | 9 | 9 | 9 |
| 5 | 11 | 11 | 11 |
| 6-12 | 20 | 5 | 8 | 8 | 8 |
| 5 | 11 | 11 | 11 |
| 5 | 14 | 14 | 14 |
| 5 | 17 | 17 | 17 |

**3. RESULT & DISCUSSION**

**3.1 The thawing of skin**

In the 0–6 months age group, the average thawing time of the skin after freezing was 1.68±0.13 minutes for stainless steel and 1.73±0.14 minutes for brass metal (Table 2). For stainless steel, the shortest thawing time of 1.5±0.22 minutes was observed at 5 and 11 seconds of exposure. In contrast, for brass metal, the minimum thawing time was recorded at 11 seconds of exposure. There was no significant difference in thawing time between stainless steel and brass metals for their respective exposure durations. This suggests that skin thawing occurred more quickly at 5 and 11 seconds (1.5±0.22 minutes) for stainless steel and at 11 seconds (1.4±0.29 minutes) for brass, leading to faster skin healing compared to other exposure times. In the 6–12 months age group of Sahiwal cattle, the average thawing time of the skin after freezing was 1.45±0.1 minutes for stainless steel and 1.3±0.09 minutes for brass metal (Table 2). There was no significant difference in thawing time between stainless steel and brass metals for their respective exposure durations. The quickest thawing occurred at 8 seconds (1.1±0.1 minutes) for stainless steel and 17 seconds (1.1±0.1 minutes) for brass, leading to faster skin healing compared to other exposure times. Overall, the thawing time for all metal types ranged from a minimum of 1.1±0.1 minutes to a maximum of 1.7±0.2 minutes (Table 2). These findings closely align with Hooven (1968), who reported that skin thawing occurred within 2 minutes. Additionally, Bertram et al. (2006) also observed that skin thawed within a few minutes.

**Table 2 Mean time of thawing of skin using various metals of same dimension in a given exposure time**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age Group | **0 to 6 months** | | | | Overall | **6 to 12 months** | | | | Overall |
| **Exposure Time**  (Seconds) | 5 | 7 | 9 | 11 |  | 8 | 11 | 14 | 17 |  |
| **Stainless steel** | 1.5±0.22 | 2±0.27 | 1.7±0.3 | 1.5±0.22 | 1.68±0.13 | 1.5±0.22 | 1.5±0.22 | 1.7±0.2 | 1.1±0.1 | 1.45±0.1 |
| **Brass** | 1.8±0.37 | 1.8±0.19 | 1.9±0.24 | 1.4±0.29 | 1.73±0.14 | 1.1±0.1 | 1.4±0.19 | 1.3±0.2 | 1.4±0.24 | 1.3±0.09 |

Values superscripted by different letters differed significantly from each other in a column \*P<0.05

**3.2 Development of oedema**

In the 0–6 months age group of Sahiwal cattle, the average time for the onset of oedema following freezing was 12.98±0.74 minutes for stainless steel and 11.34±0.38 minutes for brass metal (Table 3). Oedema development occurred more quickly at 9 and 11 seconds of exposure (11.8±0.66 and 9.8±1.16 minutes, respectively) compared to 7 seconds (16±1.68 minutes), showing a significant difference (P<0.01). Overall, a downward trend was observed in the time required for oedema development as exposure time increased in this age group. For stainless steel, the time required for oedema onset gradually decreased, except at 7 seconds of exposure, where it took 16±1.68 minutes. In the 6–12 months age group, the average time for oedema onset was 13.5±1.01 minutes for stainless steel and 14.05±0.97 minutes for brass metal (Table 3). In both metals, oedema development showed an increasing trend with longer exposure times. However, using brass metal, the oedema onset at 8, 11, and 14 seconds differed significantly (P<0.05) from that at 17 seconds. Overall, these findings are consistent with those of Bertram et al. (2006), who observed noticeable swelling in the branded area within minutes. However, Torell et al. (2001) reported that the swelling pattern emerged within 5 to 10 minutes.

**Table 3 Mean time for development of oedema using various metals of same dimension in a given exposure time**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age Group | **0 to 6 months** | | | | Overall | **6 to 12 months** | | | | Overall |
| **Exposure Time**  (Seconds) | 5 | 7 | 9 | 11 |  | 8 | 11 | 14 | 17 |  |
| **Stainless steel** | 14.3±0.49bc | 16±1.68c | 11.8±0.66ab | 9.8±1.16a | 12.97±0.74\*\* | 11.2±0.97 | 12.2±0.86 | 13±1.14 | 17.6±3.2 | 13.5±1.01 |
| **Brass** | 11±0.45 | 12.2±0.58 | 12.3±0.66 | 9.8±0.86 | 11.32±0.38 | 11.6±0.68a | 12±0.63a | 14.2±1.11ab | 18.4±2.94b | 14.05±0.97\* |

Values superscripted by different letters differed significantly from each other in a column \*\*P<0.01 & \*P<0.05

**3.3 Persistency of oedema**

An average persistency time of oedema following freezing was observed to be 23.55±0.63 hours for stainless steel and 23.2±0.66 hours for brass metal (Table 4). This duration ranged from 21.2±1.46 hours (minimum) to 25.6±0.92 hours (maximum) in Sahiwal cattle aged 0 to 6 months. In the case of brass metal, the persistency of oedema for an exposure time of 9 seconds (25.6±0.92 hours) was significantly different (P<0.05) from that of 5 and 11 seconds (21.4±1.20 and 21.4±1.36 hours, respectively). For the 6 to 12 months age group of Sahiwal cattle, the average persistency time of oedema following freezing was 21.65±0.65 hours for stainless steel and 21.5±0.77 hours for brass metal (Table 4). The differences in oedema persistency time across all exposure durations in this age group for both stainless steel and brass metals were non-significant. Similar findings were observed by Hooven (1968) who reported that marked oedema persist for 24 to 48 hours. However, Torell et al. (2001) reported that the skin was swollen for the period of 48 to 72 hours after freeze branding.

**Table 4 Mean time for persistency for oedema using various metals of same dimension in a given exposure time**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age Group | **0 to 6 months** | | | | Overall | **6 to 12 months** | | | | Overall |
| **Exposure Time**  (Seconds) | 5 | 7 | 9 | 11 |  | 8 | 11 | 14 | 17 |  |
| **Stainless steel** | 24±1.1 | 24.8±0.58 | 24.2±1.36 | 21.2±1.46 | 23.55±0.63 | 21.4±0.75 | 21.6±0.68 | 20±1.67 | 23.6±1.63 | 21.65±0.65 |
| **Brass** | 21.4±1.20a | 24.4±0.74ab | 25.6±0.92b | 21.4±1.36a | 23.2±0.66\* | 19.8±1.46 | 21.6±1.29 | 22.8±1.46 | 21.8±2.01 | 21.5±0.77 |

Values superscripted by different letters differed significantly from each other in a column \*P<0.05

**3.4 Dryness of skin**

The average number of days required for skin dryness following freezing was **7.15 ± 0.86** and **8.05 ± 0.68** for stainless steel and brass metals, respectively (Table 5). In Sahiwal cattle, skin dried faster after freeze branding at **7- and 9-second** exposure times, followed b**y 5 and 11second** exposure times. For stainless steel, the exposure times of **7 and 9 seconds** differed significantly (**P<0.01**) from those of **5 and 11 seconds**. In brass metal, the **7 and 9 second** exposure times differed significantly (**P<0.05**) only from the **11 second** exposure time. At a **7 second** exposure time, the duration of **edematous swelling** was longer, whereas skin dryness occurred more quickly (Table 5) in the **0 to 6 month** age group using stainless steel. In Sahiwal cattle aged **6 to 12 months**, the average time required for skin dryness was **9.6 ± 0.86** and **10.75 ± 0.98** days for stainless steel and brass metals, respectively. For stainless steel, the number of days required for skin dryness at **8 and 11 second** exposure times differed significantly **(P<0.05**) from that at **17 second** exposure time (**13 ± 1.64 days**). Similarly, when brass metal was used, the **17 second** exposure time (**14.6 ± 2.25 days**) differed significantly (**P<0.05**) from the **8 and 11 second** exposure times (Table 5). For both metals, skin dryness occurred significantly (**P<0.05**) faster at shorter exposure times. Overall, it can be concluded that skin dryness was more pronounced with stainless steel, followed by brass. **Hooven (1968) reported similar findings; however, he studied only one metal in his experiment.**

**Table 5 Mean time for dryness of skin using various metals of same dimension in a given exposure time**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age Group | **0 to 6 months** | | | | Overall | **6 to 12 months** | | | | Overall |
| **Exposure Time**  (Seconds) | 5 | 7 | 9 | 11 |  | 8 | 11 | 14 | 17 |  |
| **Stainless steel** | 9.8±1.74b | 4±0.32a | 4.8±1.11a | 10±1.41b | 7.15±0.86\*\* | 6.4±1.29a | 8±1.05ab | 11±1.38bc | 13±1.64c | 9.6±0.86\* |
| **Brass** | 8.2±1.24ab | 6.8±0.86a | 6.2±1.15a | 11±1.30b | 8.05±0.68\* | 8±1.7a | 8.6±1.54a | 11.8±0.86ab | 14.6±2.25b | 10.75±0.98\* |

Values superscripted by different letters differed significantly from each other in a column \*\*P<0.01 & \*P<0.05

**3.5 Formation of scab and its persistency**

In Sahiwal, the average time for formation of scab and its persistency were 16.65±1.18 and 18.8±0.81 days for stainless steel and brass metals, respectively in 0-6 months of age (Table 6). In stainless steel metals, the time required for scab formation and its persistency at 11 seconds of exposure time differed significantly (P<0.01) from rest of the exposure time. This result indicated that more days were required for scab formation and its persistency at higher exposure time (11 seconds) whereas, in this age group of similar exposure time (11 seconds) the time required for development of oedema was significantly (P<0.05) lesser (9.8±1.16 minutes) (Table 6) in stainless steel metal. However, in brass metal no significant result was seen. In 6 to 12 months of age group, the average time required for formation of scab and its persistency in present investigation was found to be 19.4±0.73 and 20.3±0.87 days for stainless steel and brass metals, respectively (Table 6). In brass metal, a significant difference (P<0.05) were noticed between the time required for scab formation and its persistency for the exposure time of 11 and 17 seconds (Table 6). That means higher the exposure time (17 seconds) more days will be required for scab formation and its persistency.. In stainless steel metals increasing trend for scab formation and its persistency were seen in 6 to 12 months age group Sahiwal. However, these findings were in accordance with the findings of Bath et al. (1981) and Bertram et al. (2006) observed 3 to 4 weeks of time which is little higher than the required days for formation of scab and its persistency.

**Table 6 Mean time for scab formation and its persistency using various metals of same dimension in a given exposure time**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age Group | **0 to 6 months** | | | | Overall | **6 to 12 months** | | | | Overall |
| **Exposure Time**  (Seconds) | 5 | 7 | 9 | 11 |  | 8 | 11 | 14 | 17 |  |
| **Stainless steel** | 16.8±2.18a | 11.8±0.2a | 15.6±2.01a | 22.4±1.78b | 16.65±1.18\*\* | 17±1.87 | 18±0.55 | 21±1.14 | 21.6±1.12 | 19.4±0.73 |
| **Brass** | 20±1.26 | 16.8±1.39 | 17.4±1.69 | 21±1.70 | 18.8±0.81 | 18.6±0.98a | 18±1.3a | 20.4±1.12ab | 24.2±2.18b | 20.3±0.87\* |

Values superscripted by different letters differed significantly from each other in a column \*\*P<0.01 & \*P<0.05

**3.6 Appearance of white hairs**

The average time for the appearance of white hairs on the skin was **46.63 ± 1.97** days for stainless steel and **50.93 ± 1.3** days for brass metals in 0-6 months of age group (Table 7). A shorter time was observed for the appearance of white hairs at **5 and 9 second** exposure times (**44.75 ± 3.79** and **45.75 ± 5.57** days, respectively) using stainless steel. However, all values were **non-significantly different** across metals and exposure times in this study. The present findings align with those of **Sherwin et al. (2002),** who reported that the regrowth of white hairs occurred within **22 to 60 days** (average **36 days**). Similar finding reported by Nandanwar **et al. (2017) suggested that white hairs appeared on the skin of cattle within 41 to 51 days.** In the **6 to 12 month** age group, the average time required for the appearance of white hairs following freezing was **46.78 ± 1.96** and **50.2 ± 1.42** days for stainless steel and brass metals, respectively (Table 7). In this study, a relatively shorter time was required for white hair appearance at **8 to 11 second** exposure times using both metals. These results (Table 7) are in agreement with the findings of Nandanwar **et al. (2017) and Bertram et al. (2006),** who reported that white hair growth appeared within **six weeks**.

**Table 7 Mean time for appearance of white hairs using various metals of same dimension in a given exposure time**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age Group | **0 to 6 months** | | | | Overall | **6 to 12 months** | | | | Overall |
| **Exposure Time**  (Seconds) | 5 | 7 | 9 | 11 |  | 8 | 11 | 14 | 17 |  |
| **Stainless steel** | 44.75±3.79 | 47.6±3.33 | 45.75±5.57 | 49.50±2.50 | 46.63±1.97 | 45.6±5.03 | 45.5±3.18 | 48±2.08 | 50.5±1.50 | 46.78±1.96 |
| **Brass** | 49±1.83 | 50.66±2.33 | 48.75±3.94 | 55.25±1.75 | 50.93±1.3 | 47.2±2.4 | 49.75±1.75 | 56.66±2.40 | 49.66±3.28 | 50.2±1.42 |

**3.7 Legibility of freeze brand**

The frequency of legible white hairs on the animals using for stainless steel metal were 80, 100, 80 and 40 percent, respectively for 5, 7, 9 and 11 seconds of exposure time. However, 80, 60, 80 and 80 per cent of legible white hairs were observed using brass metal for above mentioned exposure time used in 0 to 6 months of age group of Sahiwal (Table 8). 100 percent legibility was seen in 7 seconds of exposure time using stainless steel metal. Considering this level of acceptability, 80 per cent legibility was seen at 5 and 9 seconds of exposure time in stainless steel brand. Overall, in this age group, the exposure time recommended for stainless steel and brass metals are 5 to 7 seconds and 5 seconds, respectively (Table 8). Similar finding reported by Nandanwar **et al. (2017) suggested that legibility of white hairs using stainless steel metal varied from 40 to 100 percent.** In age group of 6 to 12 months, 100 per cent legibility of white hairs was seen at 8 seconds of exposure time, while it was 80 per cent at 11 seconds of exposure time. In stainless steel and brass metal where 80 to 100 per cent legible white hairs were observed at 11 to 8 seconds of exposure time, respectively (Table 8). Therefore, in this age group (6 to 12 months) all the brands used could be recommended with an exposure time ranging from 8 to 11 seconds

**Table 8 Mean value of frequency (in percentage) of legible white hairs using various metals of same dimension on the animals for given exposure time**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Age Group | **0 to 6 months** | | | | Chi square | **6 to 12 months** | | | | Chi square |
| **Exposure Time**  (Seconds) | 5 | 7 | 9 | 11 |  | 8 | 11 | 14 | 17 |  |
| **Stainless steel (%)** | 80 | 100 | 80 | 40 | 5.064 | 100 | 80 | 60 | 40 | 4.758 |
| **Brass (%)** | 80 | 60 | 80 | 80 | 0.798 | 100 | 80 | 60 | 80 | 2.5 |

**4. CONCLUSIONS**

A **100 percent** legibility of white hairs was observed at **7 seconds** of exposure time using stainless steel during freeze branding in Sahiwal cattle. For the **0 to 6 month** age group, an exposure time of **5 to 7 seconds** is recommended for stainless steel metal. In the **6 to 12 month** age group, legibility varied from **40 to 100 percent** for stainless steel and **60 to 100 percent** for brass metal. **80 to 100 percent** legible white hairs were observed at **11 to 8 second** exposure times for stainless steel and brass, respectively. Therefore, in this age group (**6 to 12 months**), all metals used in this experiment can be recommended with an **exposure time of 8 to 11 seconds**.

. **REFERENCES**

Bath, D., Dickinson, F. & Appleman, R.H.A. (1981). Dairy Cattle Principles, Practices, Problems, Profits. 3rd Edition, K. M. Varghese Company, pp. 416-418.

Bertram, J., Gill, B. & Coventry, J. (2006). Freeze branding, *Agnote Animal Production*, alice Springs J., **15**, 1-5.

Farrell, R. K. (1966). Cryobranding, *J. Dairy Sci.,* 51(1), 146-152.

Farrell, R. K., Hosttelter, R. I. & Johnson, J. B. (1978). Freeze marking farm animals, *Pacific Northwest Bulletin*, 173, 1-8.

Hall, J. B., Greiner, S. P. & Gregg, C. (2004). ‘Cattle identification: Freeze branding’, 400-301.

Hooven, N. W. Jr. (1968). Freeze branding for Animal identification, *J. Dairy Sci.,* 51(1), 146-152.

Keys, J. E., Hooven, N. W., Weinland, B. T. & Miller, R. H. (1977). Effect of anatomical site, exposure time, age, refrigerant and breed on legibility of freeze marks on dairy cattle, *J. Dairy Sci.,* 60(7), 1163-1168.

Lay, D. C. F., Randel, R. D., Bowers, C. L. & Grissom, K. K. (1990). Effect of freeze or hot iron branding of CB cattle on some physiological indicators of stress, *J. of Anim. Sci*., Abstract 68 (Suppl. 1).

Mishra, S., Roy, S., Bhonsle, D. & Chourasia, S. K. (2005). Determination of exposure time for freeze branding in sahiwal breed, *J. Agri.,* 10(1), 13-19.

Nandanwar, A. K., Mishra, S., Bhonsle, D., Khune, V., & Dubey, A. (2015). Copper metal freeze branding in sahiwal cattle, *Indian Veterinary Journal*, 92(11), 53-455.

Nandanwar, A. K., Mishra, S., & Thakur, D. (2017). Performance of brass metal during freeze branding in sahiwal cattle, *Journal of Plant Development Sciences*, 9(7), 727-729.

Nandanwar, A. K., Kerketta, N., & Mishra, S. (2017). Comparative evaluation on performance of copper and stainless steel metal freeze branding in sahiwal cattle, *International Journal of Current Micribiology and Applied Sciences*, 6(11), 3130-3138.

Newton, D. (1978). Freeze branding, Pages 142-144 in B. Stone-house, editor. Animal marking, University park, Baltimore, Maryland, USA and MacMillan, London, United Kingdom.

Sherwin, R. E., Haymond, S., Stricklan, D. & Olsen, R. (2002). Freeze branding to permanently mark bats. Wildlife Society Bulletin, 30(1), 97-100.

Snedecor, G. W. & Cochran, W. G. (1994). Statistical methods. 8th edition, Iowa State University Press, Iowa, USA.

Steel, R. G. D. & Torrie, J. H. (1984). Principles and procedures of statistics, A Biometrical approach, 2nd edition, McGraw – Hill International Book Company.

Torell, R., & Riggs, W. N. (2001). Freeze Branding Ranch Animals, University of Nevada Cooperative Extension, Fact Sheet 01-25.

Wagner, R. W., Helmondoller, R., & Pritchard, J. (2000). Beef cattle. Extension Service, West Virginia University.

Whittier, J. C. & Ross, E. J. 1993. Agricultural publication, GO2202-Reviewed.