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The Success Rate of Non-Penetrative Pre-Slaughter Stunning on Australian Brahman Cross Cattle Slaughter in Indonesia

(Tingkat Keberhasilan Non-Penetrative Pre-Slaughter Stunning Pada Penyembelihan Sapi Australian Brahman Cross di Indonesia)

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ABSTRACT

This study was conducted to evaluate the success rate of non-penetrative pre slaughter stunning (NPPSS) and the factors that influence it in 460 Australian Brahman cross cattle. Observations were made on the handling of cattle, the implementation of NPPSS, the slaughtering process until the animal was declared dead. The results showed that the stunning success rate of NPPSS (SSR) was 74.35%. Ordinal regression analysis of the six observed parameters, three parameters have a significant influence on SSR: shooting placement area (ASP), shooting placement distance (DSP), and the presence of frontal and nuchal eminence (FE, NE). The ASP at the point of the cross line between two lines from the center of the dorsal eye to the center of the contralateral horn base, DSP at a low position (DSP<3 cm), and presence of FE gave a relatively low of SSR. Thus, it can be concluded that the SSR of the use of NPPSS in Indonesia is relatively low and is influenced by ASP, DSP, and the presence of FE and NE.
Keywords: head shape, non-penetrative, shooting placement, stunning, unconsciousness

ABSTRAK

Penelitian ini dilakukan untuk mengetahui tingkat keberhasilan penggunaan *non-penetrative pre slaughter stunning* (NPPSS) dan faktor yang memengaruhinya pada 460 sapi *Australian Brahman cross*. Pengamatan dilakukan pada penanganan sapi, pelaksanaan NPPSS, penyembelihan hingga hewan mati. Hasil penelitian menunjukkan bahwa tingkat keberhasilan NPPSS (TKS) adalah 74,35%. Analisis regresi ordinal dari enam parameter yang diamati, tiga parameter memiliki pengaruh signifikan terhadap TKS: area *shooting placement* (ASP), jarak *shooting placement* (JSP), dan keberadaan *frontal* dan *nuchal eminence* (FE, NE). Pada ASP di titik persilangan antara dua garis dari bagian dorsal tengah mata ke bagian tengah pangkal tanduk kontralateral, DSP pada posisi rendah (DSP<3 cm), dan adanya FE memberikan TKS yang relatif rendah. Dengan demikian, dapat disimpulkan bahwa SSR penggunaan NPPSS di Indonesia relatif rendah dan dipengaruhi oleh ASP, DSP, serta adanya FE dan NE.
Kata kunci: bentuk kepala, ketidaksadaran, non-penetrative, non-penetrative, shooting placement, stunning

INTRODUCTION

Non-penetrative pre-slaughter stunning is a mechanical stunning that is permitted in Indonesia. A non-penetrative captive bolt has a mushroom-headed bolt tip that hits the skull but does not enter the brain. If done correctly, stunning can cause a concussion so that the animal is unconscious and does not feel pain when slaughtered (Fuseini *et al*., 2017; Limon *et al*., 2010). The operator's skills, animals, facilities, and equipment influenced the effectiveness of stunning in the field (Riaz *et al*., 2021). It is necessary to have good restraint facilities, sufficient power, and data regarding the animal's anatomy to get a good stun (Hewitt, 2016).

The Indonesian Ulema Council (MUI) has issued guidelines for implementing NPPSS. The requirements are strict: it does not cause the animal to die before slaughter and does not cause permanent defects, especially in the central nervous system (LPPOM MUI, 2012). In addition, in the Indonesian National Standard for halal ruminant slaughter, the NPPSS process is allowed in SNI 99003 2018 (BSN, 2018). The controversy of the NPPSS relates to the existence of two different opinions in society. In the group that opposes NPPSS, there is an assumption that NPPSS can harm animals. On the other hand, some people doubt the halal status of meat from NPPSS cattle. Meanwhile, the group that accepted the implementation of the NPPSS assumed that the NPPSS was in the context of implementing animal welfare and still met the halal criteria (Fuseini *et al*., 2016). The polemic about the pros and cons of using the NPPSS is due to the limited data regarding the evaluation of NPPSS. Both groups do not have valid documented data regarding the the NPPSS in Indonesia.

This study aims to evaluate the NPPSS in Indonesia and the factors that influenced it. The factors that influenced the success rate of NPPSS need to be identified to improve the implementation of animal welfare in the slaughtering process.

MATERIALS AND METHODS

Materials

This research is a field study of 23 slaughterhouses in Java and Sumatra, Indonesia. Observations were made on 460 ABX cattle with a bodyweight range of 350–700 kg using the Magnum Cash Knocker Stunner (0.25-caliber; Accles and Shelvoke, Sutton Coldfield, UK). The NPPSS process was performed using simple restraining boxes (MLA-Livecorp Mark I Australia). This research has been approved by IPB University ethics commission No. 111a/SKE/KEH/X/2018.

Methods

The study was conducted on normal abattoir activities. Two observers observed and recorded the process: before, during, and after slaughter until the animal died. Head morphometric measurements were carried out after the head was separated from the body. Observations of the NPPSS include 13 parameters on the stunning success rate of stunning (SSR): body weight (BW), sexes, incisor condition, stunner men, stunning strength (SS), door closed–stunning final interval (DCFS), number of shots (NS), broken skull (BS), presence of horns (H), head width (HW), shooting placement area (ASP), shooting placement distance (DSP), and frontal, and nuchal eminence (FE-NE) conditions.

Pre-stunning

The body weight of the cattle was grouped into cattle with a weight of under 450, 450–550, and over 550 kg. This body weight is used to determine standard of the SS (cartridge): orange cartridges are used for <450 kg cattle, black cartridges for 450–550 kg cattle, and red cartridges for >550 kg cattle. Based on the strength of the NPPSS used, the strength of the NPPSS is divided into three groups: NPPSS with low (stunned with lower cartridge), standard (stunned with the appropriate cartridge), and high strength (stunned with a higher cartridge). Stunner men are grouped into two (1–2): not certified and certified competency/training.

Stunning process

In the NPPSS process, the DCFS were grouped into five (1–5): ≥121, 91–120, 61–90, 31–60, and ≤30 seconds. The NS is grouped into two (1–2): NS=1 and NS>1. The SSR refers to the Stun Quality Rating (SQR) according to Atkinson *et al*. (2013) at the level of SQR 2 (nystagmus, full eyeball rotation) and SQR 3 (failure to collapse, reflexes to righting posture, vocalization, response to painful stimuli, corneal reflexes, blinking and regular breathing), as well as indicators of unconsciousness according to Verhoeven *et al*. (2016). The SSR was categorized into four (1–4): NS>1, not fully unconscious; NS>1, unconscious; NS=1, not fully unconscious; and NS=1, unconscious

Post stunning

Broken skull is grouped into five (1–5): no damage, bruises, cracks, cracks and shifts, cracks and holes. The incisor teeth is grouped into five (1–5): not yet changed incisors, cattle have changed in the first, second, third, and fourth incisors. The horns were divided into three groups: hornless, scar-shaped horns and the presence of real horns. Head width was measured from the center of the dorsal eye (CDE) to the contralateral of the center of horn base (CHB). Head width was grouped into three: narrow (≤24cm), medium (25–27 cm), and wide (≥28cm). Observations on SP divided into two parameters: shooting placement area (ASP) and shooting placement distance (DSP) (Figure 1). The ASP is grouped into four: at the intersection of two imaginary lines from CDE to CHB; above, below, and lateral to the cross line. Observations of DSP parameters were grouped into three: low (<3cm), recommendation (3–5 cm) and high (≥6cm) calculated from the point of intersection between two imaginary lines from the CDE to the contralateral CHB to the center of the SP. The FE and NE conditions were categorized by observing the presence of dorsal protrusion of the FE and the caudodorsal elevation of the NE. The FE and NE conditions were grouped into four: high FE and NE, high FE, high NE, and no elevation of FE and NE.

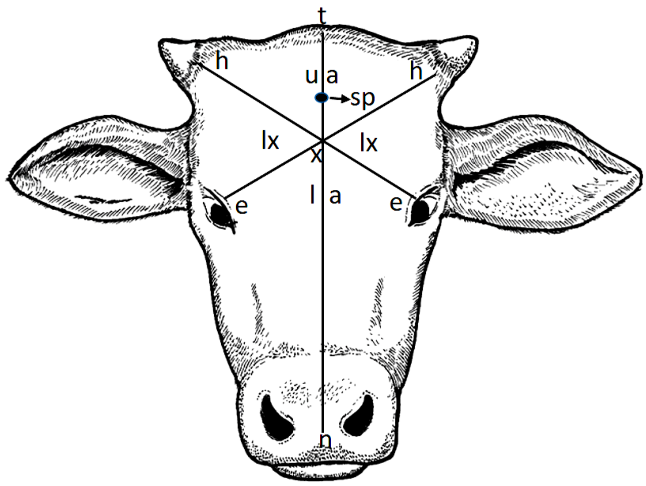

Figure 1. Area of SP based on two imaginary lines drawn from the CDE to the CHB. Note: e: CDE, h: CHB, n: nose, t: top of the head, x: cross-section point, la: lower area, lx: lateral area, ua: upper area, t-n: midline of the head, sp: actual SP.

Data Analysis

`The data obtained were analyzed descriptively using SPSS 21. All research parameters were tested using the Chi–Square Test with a confidence interval of 0.75% to determine the candidate parameters that influenced. The Chi-Square Test results with $p<0.25$ were followed by a test using ordinal regression with a confidence interval of $p<0.05$.

RESULTS

The SSR was grouped into two: cattle with NS=1 is 409 heads (88.9%), and cattle with NS>1 is 51 heads (11.1%) (Table 1). The SSR in the two groups was different. In the cattle that received NS=1, 342 heads (83.6%) were slaughtered in a state of unconsciousness, and 67 heads (16.4%) were slaughtered in a state of not fully unconscious. While the SSR cattle with NS>1 were 33 heads (64.7%), and as many as 18 heads (35.3%) were slaughtered in a state not fully unconscious. Overall, the success rate of unconscious cattle with NS=1 was 74.35% of the total number of cattle (Table 1).

Based on the Chi–Square test, of the 13 parameters observed, six parameters are thought to have a strong correlation with SSR ($p<0.25$). The six parameters are DCFS interval, BS, H, ASP, DSP, FE and NE then tested with ordinal regression to find out which factors correlated significantly with SSR. The parameters that correlate with SSR are ASP, DSP, and FE and NE conditions. In the ASP, shooting precisely at the cross point between the two imaginary lines from CDE to CHB resulted in the SSR of 0.29 (0.09–0.94) compared to shooting above the cross line ($p<0.05$). In line with ASP, DSP also has a significant influence, low DSP resulted in only 0.06(0.03–0.15) SSR compared to shots at the recommended DSP. The presence of FE and NE also has a significant correlation to SSR. The SSR of cattle with high FE and NE, high FE, high NE have 0.06(0.02–0.15), 0.05(0.02–0.18), and 0.26(0.08–0.82) respectively compared to SSR of cattle without FE and NE (Table 2).

DISCUSSION

The success rate of NPPSS

The effectiveness of NPPSS in can fulfill the aspects of animal welfare if it can induce unconsciousness on the first shot (Terlouw *et al*., 2016). In this study, the SSR on the NS=1 was 74.35%, lower than reported by Gibson *et al*. (2019) (82%), Oliveira *et al*. (2018a) (91%), and 100% in young calves (Bartz *et al*., 2015). When compared with penetrative stunning, the SSR on the NS=1 is much lower than 90.8% (Von Wenzlawowicz *et al*., 2012), 87.5% (Atkinson *et al*., 2013), 99% (Oliveira *et al*., 2018a), and 100% (Gibson *et al*., 2019, Kline *et al*., 2019). EFSA (2004) did not recommend the use of NPPSS in Europe because of concerns over its effectiveness in different age/weight of animals.

The strength of the NPPSS conducted in Indonesia is generally lower in the range of 160–190 psi, compared to Gibson *et al*. (2019) (210–220 psi) and Oliveira *et al*. (2018a) (220 psi). The low strength of NPPSS is thought to contribute to the overall low SSR in cattle

Table 1. The stunning success rate of NPPSS based on NS

Parameter	Stunning Success Rate (N (%))				Total
	NS>1, conscious	NS>1, unconscious	NS=1 conscious	NS=1 unconscious	
Number of Shoot >1	18(35.3)	33(64.7)	0(0.0)	0(0.0)	51(11.1)
Number of Shoot =1	0(0.0)	0(0.0)	67(16.4)	342(83.6)	409(88.9)
Total	18 (3.91)	33 (7.17)	67 (14.57) 35 (7.6 SQR2) 32(7 SQR 3)	342(74.35)	460 (100)

Table 2. Risk factors analysis of stunning success rate in slaughter using NPPSS.

Parameter	Stunning success rate of NPPSS (N (%))				Total	Odds Ratio	p
	NS>1, conscious	NS>1 unconscious	NS=1 conscious	NS=1 unconscious			
Door-closed stunning final stunning interval (DCFS)							
>121 second	5(20.0)	7(28.0)	1(4.0)	12(48.0)	25(5.4)	0.90(0.22-3.67)	0.88
91-120 second	4(19.0)	2(9.5)	2(9.5)	13(61.9)	21(4.6)	0.96(0.22-4.04)	0.96
61-90 second	2(4.7)	6(14.0)	7(16.3)	28(65.1)	43(9.3)	0.99(0.33-3.04)	0.99
31-60 second	3(3.4)	7(8.0)	10(11.5)	67(77.0)	87(18.9)	1.27(0.52-3.12)	0.60
0-30 second	4(1.4)	11(3.9)	47(16.5)	222(78.2)	284(61.7)	Reference	
Broken Skull Criteria (BS)							
No damage	7(6.4)	5(4.6)	24(22.0)	73(67.0)	109(23.7)	0.14(0.01-1.43)	0.10
Bruising	2(1.6)	5(4.0)	16(12.8)	102(81.6)	125(27.2)	0.39(0.04-4.03)	0.43
Cracks	2(1.3)	16(10.7)	21(14.1)	110(73.8)	149(32.4)	0.83(0.08-8.28)	0.87
Cracks and shifted	6(8.6)	7(10.0)	5(7.1)	52(74.3)	70(15.2)	0.84(0.08-9.02)	0.88
Cracks, shifted, & holes	1(14.3)	0(0.0)	1(14.3)	5(71.4)	7(1.5)	Reference	
Presence of Horn (H)							
No horn	11(4.8)	11(4.8)	(18.6)	166(71.9)	231(50.2)	1.37(0.58-3.23)	0.48
Scar	3(3.3)	11(12.2)	11(12.2)	65(72.2)	90(19.6)	1.21(0.43-3.39)	0.72
Permanent horn	4(2.9)	11(7.9)	13(9.4)	111(79.9)	139(30.2)	Reference	
Area of Shooting Placement (ASP)							
Cross section point	1(3.6)	2(7.1)	19(67.9)	6(21.4)	28(6.1)	0.29(0.09-0.94)*	0.04
Under cross section	0(0.0)	0(0.0)	1(100)	0(0.0)	1(0.2)	0.00	0.95
Lateral cross section	0(0.0)	0(0.0)	1(50.0)	1(50.0)	2(0.4)	0.24(0.00-13.48)	0.49
Upper cross section	17(4.0)	31(7.2)	46(10.7)	335(78.1)	429(93.3)	Reference	
Distance of Shooting Placement (DSP)							
Low	10(11.6)	3(3.5)	41(47.7)	32(37.2)	86(18.7)	0.06(0.03-0.15)*	0.00
High	0(0.0)	1(4.5)	1(4.5)	20(90.9)	22(4.8)	1.00(0.12-8.69)	1.00
Recommendation	8(2.3)	29(8.2)	25(7.1)	290(82.4)	352(76.5)	Reference	
Presence of frontal eminence (FE) and nuchal eminence (NE)							
FE and NE	7(14.9)	1(2.1)	22(46.8)	17(36.2)	47(10.2)	0.06(0.02-0.15)*	0.00
FE	2(7.4)	3(11.1)	12(44.4)	10(37.0)	27(5.9)	0.05(0.02-0.18)*	0.00
NE	2(6.5)	1(3.2)	6(19.4)	22(71.0)	31(6.7)	0.26(0.08-0.82)*	0.02
No FE and NE	7(2.0)	28(7.9)	27(7.6)	293(82.5)	355(77.2)	Reference	
Total	18(3.9)	33(7.2)	67(14.6)	342(74.3)	460(100)		
OR	0.00 (0.00-0.00)	0.00 (0.00-0.00)	0.02 (0.00-0.18)*	Reference			
p	0.86	0.90	0.001				

Note: * There is a significant association at $p < 0.05$, Na: not analysis with NS=1. In zebu cattle, penetrative stunning with a power less than 190 psi showed higher rhythmic breathing, lower tongue protrusion and relaxation of the masseter muscles, and a higher number of shots compared to cattle stunned at 190 psi (Oliveira *et al*., 2018b).

The use of low-strength NPPSS in Indonesia is due to the NPPSS acceptance criteria in HAS 23103 (LPPOM MUI, 2012), which is based on skull damage. In HAS 23103, NPPSS can be accepted by halal standards if the skull does not damage or only bruised. If the NPPSS causes cracks, cracks and shifts, cracks and penetrates the brain, it does not meet the halal requirements. Since 2018, Indonesia has had a national standard for the halal slaughter of ruminants, SNI 99003 2018 (BSN, 2018). The criteria of SNI 99003 2018 for skull damage are simplified to only two: penetrating and not penetrating the brain. NPPSS is still acceptable if the skull damage does not penetrate the brain and the cattle still have vital signs of life (*Hayatul Mustaqirah*). The cattle with BS penetrate the brain, they do not meet the halal requirements because they are considered penetrative stunning.

A low SSR is a serious finding from an animal welfare point of view. The 25.65% of cattle that were not fully unconscious at NS=1 still showed at least one of the parameters SQR 2 (35 heads/7.6%). Meanwhile, 18.05% (83 heads) still show SQR 3. Cattle with SQR2 have a moderate risk of welfare, while cattle with SQR3 have a high risk of welfare (Atkinson *et al*., 2013). The SSR with NS>1 is low at only 64.7% and 35.3% of them were slaughtered in a state not fully unconscious even though they had received NS>1. Thus, these cattle experience pain from stunning NS>1 and the process of slaughtering. According to Fries *et al*. (2012), the number of shots more than one time should get serious attention because the cattle cannot consider having received a non-harmful procedure.

The SSR at NS=1 is an essential indicator of animal welfare. When comparing NPPSS and penetrative stunning, the second stunning frequency is higher in NPPSS: 46% versus 2% (Neves *et al*., 2016). In this study, the SSR of NPPSS with NS=1 was only 74.35%, but the second stunning was only performed in 11% (51 heads). The 7.6% (35 heads) cattle with SQR2 and 7% (32 heads) did not perform a second stunning even though they had an SQR3. The limited cartridges caused the second stunning only to be performed on cattle that showed SQR3 criteria that did not collapse.

In NPPSS, the skull damage covers an area as wide as the mushroom head diameter of the stunner. The wide of head diameter mushroom head causes NS>1 often overlap with the SP on the first shot. At the site of the first SP, the skin may still be intact, but the underlying bone may fracture under pressure. This condition causes not all energy to be transferred into the brain (EFSA AHAW, 2020). The softened and swollen tissue absorbs some kinetic energy due to the first stunning.

Area of Shooting Placement (ASP)

Stunner men in Indonesia commonly use SP guidelines based on HAS 23103 (LPPOM MUI, 2012), which is the cross-line between two imaginary lines between CDE to the contralateral CHB. Most of SP were done at ASP above the cross line, which was 93.3%, exact at the cross point by 6.1%, lateral of the cross line by 0.4%, and below the cross line by 0.2%. The ASP exact at the cross point has a significant correlation with the SSR, which is only 0.29 (0.09-0.94) compared to the SSR of ASP above the cross line. The ASP below and lateral to the cross line did not show a significant correlation with SSR due to the limited number of animals. Head dimensions and SP affect nerve damage caused by stunning (Terlouw *et al*., 2015, Wagner *et al*., 2017). According to Gillam *et al*. (2016), the head shape with unique characteristics such as a long snout and large horns in brahman cattle causes the SP upwards of several centimeters. Most of the slaughtering cattle in Indonesia are ABX. These cattle's head shape and brain position are similar to brahman cattle. Thus the SP recommendation according to HAS 23103 is not appropriate for ABX cattle, and the SP recommendation in SNI 99003 2018 is too low for the NPPSS.

The SSR at a low DSP (<3cm) was 0.06(0.03–0.15), significantly lower compared to the recommended DSP (3–5 cm). The SSR at DSP≥6 showed relatively similar to the recommended DSP. However, there is an interesting phenomenon; six cattle stunned at a high position of SP (DSP≥8 cm) was vomiting before being slaughtered. The vomited cattle caused by high SP near the top of the head, causing disturbances in the vomiting center in the medulla oblongata.

In penetrative stunning, the ideal SP is at the intersection of the imaginary line between CDE and contralateral CHB up to a radius of 2 cm (Oliveira *et al*., 2018a, Kamenik *et al*., 2019). In NPPSS, the recommended SP is 2 cm above the SP for penetrative stunning. Twelve cattle were stunned not on the midline of the head. The SSR in stunning cattle on the right and left of the midline of the head is low at only 33.33%.

The effective stunning is determined by correct SP and may be influenced by breed (Wagner *et al*., 2017). According to Gilliam *et al*. (2016) the brain position of *Bos indicus* cattle tends to be more caudal compared to *Bos taurus* cattle. This is in accordance with the results of this study which showed DSP for ABX cattle at a position 3-5 cm above the cross line between the eyes and the contralateral horns. Based on ASP and DSP, the SP of NPPSS must be exact in the area above the cross line between the CDE to the contralateral CHB, with a recommended DSP (3-5 cm) and should be performed in the midline of the head. Shooting placement in this location will cause damage to the brain in the middle of the brain so that it can induce unconsciousness.

The most restraining boxes commonly used in Indonesia are simple restraining boxes that are not equipped with neck braces and head or chin restraints. It causes the head of the cattle to move freely and will affect the accuracy of the shooting placement. In this study, the accuracy of the SP at the recommended location is 76.5%. This level of accuracy is higher than the research of Von Wenzlawowicz *et al*. (2012), which amounts to 65% in restraining boxes that are not equipped with a head restrainer. The location and the direction of shooting angle accuracy are critical, and it can be improved by the presence of a head restrainer on the restraining box (Fries *et al*., 2012, Von Wenzlawowicz *et al*., 2012)

Presence of Frontal and Nuchal Eminence (FE-NE).

The impact of the NPPSS is in the form of extensive hemorrhage in the cerebrum but does not cause macroscopic damage to the brainstem (Oliveira 2018b). Thus, the kinetic energy transmitted into the brain to induce unconsciousness is influenced by the area of contact between the mushroom head and the surface of the head. In this study, the presence of FE and NE significantly correlated with the risk of SSR of NPPSS. Cattle with FE and NE, FE, and NE resulted in SSR of 0.06(0.02–0.15), 0.05(0.02–0.18), 0.26(0.08–0.82) compared to the cattle without FE and NE.

Frontal eminence is a dorsal elevation at the junction of the right and left frontal bones. This elevation causes the surface of the frontal bone to become convex to the midline of the head. Due to the convex surface of both frontal bone and mushroom head, the contact area between the surface of the captive bolt and the frontal bone is reduced so that the kinetic energy transmitted is also reduced. The wider contact area between the mushroom head and frontal bone might be more effective with less fracture compared to a smaller mushroom head diameter (Grandin and Cockram, 2020). This occurrence is in line with the low SSR of cattle with FE, which is 20 times lower than cattle without FE and NE. In cases of high FE, the stunnermen will shift the SP to the right or left of the midline of the head. However, this action was ineffective because the SSR in SP on the right or left side of the mid-head was shallow (33.33%).

The NE is a caudal elevation of the crista nuchalis. The presence of NE causes the head to be longer and will shift the shooting landmark. In this study, the SSR of cattle that have FE was 3.85 times lower than the cattle that did not have FE and NE. The SSR in cattle that have NE on the NS=1 was 71%. Cattle with FE and NE have low SSR, which is 16.67 times lower than cattle without FE and NE. Considering the low SSR of cattle that have FE, NE, or both can be considered in the policy of importing cattle. Cattle with FE, NE, or both are unsuitable for NPPSS, so Indonesia should not import cattle with an elevation of FE , NE and/or FE and NE.

Based on the results of this study, it can be concluded that the SSR of the NPPSS in Indonesia is still relatively low only at 74.35%. Overall, three parameters significantly influenced SSR in NPPSS: ASP, DSP, and the presence of FE and NE. The recommended shooting must be done precisely in the midline of the head, on the ASP above the cross point between the two imaginary lines drawn from the CDE to the contralateral CHB/dorsal ear, and on DSP 3–5 cm. The cattle that have an elevation of FE, NE, and both, resulted in a low SSR and are not suitable for NPPSS.

CONFLICTS OF INTEREST

We certify there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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