Meat Science 143 (2018) 159–164

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Evaluation of different captive bolt lengths and breed influence upon post-stun hind limb and forelimb activity in fed cattle at a commercial slaughter facility

Miriam S. Martin[a,*], Helen C. Kline[a], Dana R. Wagner[a], Lacey R. Alexander[b], Lily N. Edwards-Callaway[a], Temple Grandin[a]

[a] *Colorado State University, Fort Collins, Department of Animal Sciences, 1171 Campus Delivery, Fort Collins, CO 80525, USA*
[b] *Cargill Protein Group, 825 E Douglas Ave, Wichita, KS 67202, USA*

ARTICLE INFO

Keywords:
Captive bolt
Stunning
Leg activity
Abattoir

ABSTRACT

The objective of this study was to assess the effects of captive bolt length and breed type on post-stun leg activity in cattle. A total of 2850 Holstein (HOL) and non-Holstein British/Continental bred (NHOL) steers and heifers were observed post-stunning at a large commercial slaughter facility. A pneumatically powered penetrating captive bolt stunner was used with three different bolt lengths: CON, 15.24 cm; MED, 16.51 cm; and LON, 17.78 cm. Hind limb kicking, forelimb activity, take away belt stops, carcass swing and number of knife sticks during exsanguination were recorded for each animal from video recording. Hind limb and forelimb kicks observed ranged from 0 to 25 and 0 to 8, respectively. Analysis of post-stun hind limb and forelimb activity indicated that increasing pneumatically powered penetrating captive bolt length does not decrease post-stun leg activity. There was a higher percentage of cattle experiencing take away belt stops and carcass swing in HOL as compared with NHOL.

1. Introduction

Captive bolt stunning is the primary method used in US commercial beef processing plants to render cattle unconscious prior to slaughter (Algers & Atkinson, 2007; Daly, Gregory, & Wotton, 1987; Oliveira, Gregory, Dalla Costa, Gibson, & da Costa, 2017). The purpose of captive bolt stunning is to cause a deep and irreversible form of concussion (Gregory, Lee, & Widdicombe, 2007). Captive bolt stunning when performed properly, ensures that the animal is unconscious during exsanguination and subsequent dressing procedures until the heart beat ceases and death occurs (Atkinson, Velarde, & Algers, 2013; Gregory et al., 2007). Pneumatically powered penetrating captive bolt stunning causes trauma to the skull, brain, and associated blood vessels that results in hemorrhaging (Atkinson et al., 2013), and a phase of tonic convulsion, followed by clonic convulsion (Oliveira et al., 2017). Tonic convulsion is a rigid extension or contraction of the legs (Oliveira et al., 2017). The tonic phase transitions into a stage of clonic convulsion, which is often characterized by uncoordinated hind limb and forelimb movements (Gregory & Shaw, 2000). These movements can continue up until three minutes after the start of exsanguination (Terlouw, Bourguet, Deiss, & Mallet, 2015). The circuits that generate reciprocal leg movements for walking are located in the spinal cord which communicates with the brainstem (Grillner, 2011). When this line of communication is disrupted by stunning, the walking circuit becomes overactive which causes involuntary leg activity patterns (Grandin, 2013).Variation in the physical expression of clonic convulsion exists depending on stun placement, stun depth, and the amount of kinetic energy delivered to the animal's head (Atkinson et al., 2013).

Additionally, substantial animal-to-animal variation exists in hind limb and forelimb movements during the clonic phase of death (Bate-Smith & Bendall, 1949). These uncoordinated leg movements will be referred to as post-stun hind limb and forelimb activity. This variation exists in part due to factors influencing depth of unconsciousness (Oliveira et al., 2017) which is a result of consciousness not being an all-or-none phenomenon (Gregory & Shaw, 2000). The location of specific brain structures, along with their resistance to anoxia may explain the order in which different functions are lost (Terlouw, Bourguet, & Deiss, 2016). Clonic convulsions and leg movements appear in properly stunned cattle. Corneal reflex, spontaneous eye blinking, rhythmic breathing, and righting reflex are all considered signs that the animal is starting the process of returning to consciousness or has fully regained consciousness (Terlouw et al., 2016). If any of

* Corresponding author.
E-mail addresses: Miriam.Martin@colostate.edu (M.S. Martin), Cheryl.miller@colostate.edu (T. Grandin).

https://doi.org/10.1016/j.meatsci.2018.05.003
Received 12 March 2018; Received in revised form 28 April 2018; Accepted 2 May 2018
Available online 03 May 2018

these indicators are displayed, the animal should be immediately restunned (AVMA et al., 2013; Grandin, 2017; Gregory & Shaw, 2000).

There is an industry perception that Holstein cattle exhibit more post-stun limb movement compared to other *Bos taurus* beef breeds. Whether or not this is an accurate perception, and the influence of maturity and sex warrants further research. Post-stun leg activity poses a potential safety risk for employees in some slaughter facilities during exsanguination and subsequent processing steps (Grandin, 2002). Uncoordinated limb movements while the animal is being exsanguinated create a potentially unsafe environment for employees working near the stunned animals; In large U.S. slaughter plants, employees in these positions wear extensive protective equipment. Finding a method to reduce post-stun leg activity would be beneficial to worker safety. Some abattoirs routinely administer a second captive bolt stun immediately following the first, referred to as a "security knock", which is anecdotally thought to possibly reduce post-stun leg activity by causing additional damage to the brain and more hemorrhaging. Although a security knock can be applied, to remain within regulations set forth within the Humane Slaughter Act enforced by the United States Department of Agriculture (USDA) Food Safety Inspection Service (Humane Methods of Slaughter Act, 1958), the initial stun must render the animal insensible (FSIS USDA, 2013).

Another approach the beef industry has used to increase brain trauma and hemorrhaging, and potentially reduce post-stun kicking, is a longer penetrating captive bolt in the stunner. The majority of U.S. commercial beef slaughter plants use a standard-length bolt of 15.24 cm typically in the USSS-1 Jarvis pneumatically powered penetrating captive bolt stunner. Three different captive bolt lengths are commercially available for the Jarvis pneumatically powered penetrating stunner. The objective of this study was to evaluate if different captive bolt lengths affect the level of post-stun leg activity of cattle of different breed types in a commercial slaughter plant.

2. Methods

2.1. Animals, handling, facility, and slaughter process

Since all animal observations occurred post-stunning in a commercial slaughter plant, an exemption was filed and granted from the Colorado State University Institutional Animal Care and Use Committee (CSU IACUC # 091416). The study took place in the fall of 2016 in a large fed beef slaughter facility in the United States. The slaughter facility was a double shift plant operating two eight-hour shifts (A and B shift), slaughtering a total of approximately 5000 cattle per day at approximately 360 head per hour. Cattle arrived at the abattoir directly from feedlots. They were held in lairage for approximately 4–10 h and quietly moved through a center track conveyor restrainer. Animals were stunned with a pneumatically powered penetrating captive bolt gun while on the conveyor restrainer, shackled post-stunning on the left hind limb and then released onto a take away conveyor belt. An inclined conveyor lifted up the shackled animal onto the bleed rail. All cattle included in the study were under 30 months of age, as determined by assessing dentition which was performed by plant employees. Experimental cattle were randomly selected from different sources (i.e. producers) on both A and B shifts during the three data collection days. A total of 2850 cattle, 397 Holstein and 2453 non-Holstein (British/Continental) cattle were sampled randomly throughout A and B shifts in groups of approximately 50 to 150 head which varied depending on lot size, plant breaks, and line speed.

2.2. Treatments and study design

All captive bolt stunning was performed with a Jarvis USSS-1 [Jarvis Products Corp., Middletown, Connecticut, USA] pneumatically powered penetrating captive bolt gun [CBG] and associated Jarvis captive bolts. The CBG was tested at the beginning of each collection period using house air pressure in the maintenance shop between 60 and 90 PSI following standard plant protocol to ensure proper functioning and to test bolt velocity. A Jarvis Model AST-101 [Jarvis Products Corp., Middletown, Connecticut, USA] test stand for the Jarvis Model USSS-1 pneumatically powered penetrating stunner was used. For all three bolt lengths, the CBG was operated at a pressure of 200–210 PSI which was the PSI at which the commercial abattoir chose to operate. All CBG maintenance, cleaning, and adjustments were made in accordance with the slaughter facility's standard operating procedures and Jarvis recommendations.

Three captive bolt lengths were evaluated in the study: the control [CON] treatment was the standard length of 15.24 cm, the medium [MED] treatment was 1.27 cm longer than the CON, and the long treatment [LON] was 2.54 cm longer than the CON. The velocity recordings provided by the CBG manufacturer Jarvis [Jarvis Products Corp., Middletown, Connecticut, USA] were 39.50 m per second for the CON bolt, 39.14 m per second for the MED bolt, and 38.77 m per second for the LON bolt within the manufacturer recommended PSI range at 170 PSI (Jarvis Products Corp., 2017). The velocity recordings at 200 PSI provided by the manufacturer were 43.22 m per second for the CON bolt, 42.82 m per second for the MED bolt, and 42.43 m per second for the LON bolt (Jarvis Products Corp., 2017), which was the PSI at which the commercial abattoir was operating the pneumatically powered penetrating captive bolt stunner. Treatments were blocked by day; one bolt treatment was used per day for three days. On each day, the specified bolt treatment was used on both A and B shift. A total of 2850 cattle were sampled (CON, n = 399; MED, n = 1157; LON, n = 1294). Within the 2850 cattle sample, 398 were Holstein and 2452 were non-Holstein (British/Continental) cattle. The only determining factor for animal selection was hide, in order to capture breed differences between Holstein and Non-Holstein (British/Continental) cattle. Breed type was recorded as Holstein [HOL] or non-Holstein [NHOL]. Black and white hided steers and heifers who appeared to have dairy influence (based on head shape, muscle and bone conformation) were designated as Holstein. All other cattle were designated as non-Holstein; no *Bos indicus* influence was observed at the commercial slaughter facility on the designated collection days. Fewer Holstein cattle were sampled than non-Holstein as a result of the number slaughtered at the plant each day. For each of the three treatment days, the stunner operators were the same for each shift, but different between A and B shift; different shacklers rotated throughout shifts with two shacklers working at all times.

2.3. Data collection

GoPro Hero4 (GoPro, San Mateo, CA, USA) cameras were placed in the slaughter facility to record forelimb and hind limb post-stun activity. A single camera was clamped to a steel bar that was part of the facility structure overlooking the area from the take away belt up to the bleed rail stack line. After stunning, hind limb activity was recorded from the time the carcass was freely hanging up until the carcass reached the stack line (line of stunned animals awaiting exsanguination). A second camera was clamped to a steel bar that was part of the surrounding facility structure above the area where exsanguination occurred to capture forelimb activity. Battery pack extenders were utilized to increase the amount of footage that each camera could capture. Data was recorded for approximately three-hour time periods. SanDisk (Western Digital Technologies, Inc., Milpitas, CA, USA) micro SD cards were used to store GoPro footage on the cameras, with each camera having a designated SD card. Footage was downloaded from the camera SD cards at the end of each shift onto a laptop. Camera footage was analyzed at a later date by an observer trained to score post-stun activity, who was blinded to the bolt treatments.