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Assessment of risk factors contributing to carcass bruising in fed cattle at commercial slaughter facilities

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ABSTRACT: Cattle injuries can occur during transportation due to vehicle design, transport conditions, and loading or unloading procedures and lead to carcass bruising and economic loss due to decreased carcass value. The objectives of this study were to determine whether a relationship exists between trauma incurred during unloading and prevalence of carcass bruising in finished beef cattle at commercial slaughter facilities and determine related risk factors which contribute to both trauma and carcass bruising. Breed (classified as either Holstein cattle or beef breeds), sex, distance traveled, and trailer type ("fat/feeder combination" vs. "fat" trailer) were considered risk factors which may contribute to traumatic event prevalence. When carcass bruise prevalence within each lot was used as the dependent variable, breed, sex, distance traveled, traumatic event prevalence, ribeye area, fat thickness, yield grade, and average carcass weight were considered potential risk factors. Carcass bruises were categorized by location and size, according to the Harvest Audit Program Carcass Bruise Scoring System. Traumatic events were observed while cattle exited trailers onto the unloading docks, and were categorized by location on the animal. Average traumatic event prevalence per lot was 20.4% (± 1.11%). Average carcass bruise prevalence by lot was 68.2% (± 1.15%). There was an interaction between breed and trailer type when multiple linear regression was used to explore variables contributing to traumatic events observed at unloading *($P \leq 0.05$)*. Traumatic events were not associated with prevalence of carcass bruising, while average carcass weight and breed were associated with carcass bruising prevalence. Carcass bruising was more prevalent in Holstein cattle than in cattle which were predominantly beef breeds *($P \leq 0.01$)*. Average carcass weight was negatively associated with carcass bruise prevalence ($P \leq 0.05$). The association between traumatic events at unloading and carcass bruising is not significant when multiple variables are considered, indicating that bruising may occur at numerous other points prior to and during the transportation process, including loading and transport, and that other variables can contribute to carcass bruise prevalence. These areas should be explored to determine all potential causes of bruising in beef carcasses, and to help implement prevention practices.

Key words: carcass bruising, cattle, feedlot, loading, transportation, trauma

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INTRODUCTION

Bruising in fed beef cattle costs the industry approximately $35 million annually (Cargill Meat Solutions, personal communication). Bruised tissue must be discarded because it provides an ideal environment for bacterial proliferation, which poses a significant food safety concern (Marshall, 1977). In addition, bruising is an indicator of poor animal welfare during the pre-slaughter period (Broom, 2003). Hoffman et al. (1998) defined a bruise as "a tissue injury without laceration usually produced by a blunt object impacting an animal with sufficient force to cause rupture of the vascular supply and accumulation

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of blood and serum in tissues." This definition indicates that a bruise follows after the animal experiences some sort of trauma. Many potential sources of bruising have been suggested in the literature, including vehicle design, transport conditions, and loading and unloading procedures, however none of these have been explored extensively, and the trauma associated with these areas of the transport process is not addressed in fed beef cattle in the United States (Strappini et al., 2009; Strappini et al., 2013). Grandin (1980) and Broom (2003) reported that much of the bruising observed in livestock results from rough handling during loading, transport, and unloading, but clear supportive data is lacking. It's been reported that 43% of carcass bruising observed occurs at the slaughter facility, however handling practices have improved immensely since the publication of such research (McCausland & Millar, 1982). Therefore, the primary objective of this study was to determine whether a relationship exists between trauma incurred during unloading and prevalence of carcass bruising in finished beef cattle at commercial slaughter facilities. In addition, other risk factors which may contribute to carcass bruising in finished beef cattle are addressed, including breed, sex, distance traveled, carcass characteristics, and the trailer type used during transport.

MATERIALS AND METHODS

Permission to observe live animals was approved by the Kansas State University Institutional Care and Use Committee, IACUC #3598. Permission to observe animals unloading and carcasses on the line was obtained from corporate and management personnel for each slaughter facility prior to observation days. Permission to record trailer design was also obtained from the transporters and the slaughter facilities.

No treatments were assigned for this observational study. Fed beef cattle were observed at 3 commercial slaughter facilities during July and August of 2015. Lots of finished beef cattle were selected from the slaughter facility's daily slaughter order sheet. Whole lots were observed, even if the lot arrived in multiple trailers. Individual animal identification was not recorded.

To record traumatic events at unloading, a trained observer watched the cattle coming off the trailers, and counted the cattle that hit any part of the trailer during unloading. Multiple events were recorded for the individual animal if the animal experienced more than 1 traumatic event. Each traumatic event was classified by its location. Locations were specified as shoulder, back, rib, or hip areas. Some cattle experienced multiple traumatic events. Prevalence of traumatic event occurrence was calculated using the number of traumatic events observed at unloading over the total number of cattle in the trailer.

The same lots of cattle were observed by a second trained observer for carcass bruising prevalence using the Harvest Audit Program Carcass Bruise Scoring System, developed at Kansas State University (Rezac, 2013). The scoring system allows the observer to record the presence of all bruises on a carcass, their location, and the size category in which they fall. Location was determined by dividing the carcass into a grid of 9 sections (Fig. 1), and recording the presence or absence of a bruise in each section. Size of the bruises was categorized as small (< 5 cm in diameter), medium (5 o 15 cm in diameter), or large (> 15 cm in diameter). Bruise severity was not addressed, as the severity of a bruise depends on the density of the affected tissue, and the vascularity of said tissue, making such a measurement impossible in the fast-paced environment of a commercial slaughter facility in the United States (Strappini et al., 2009).

Multiple linear regression (PROC GLIMMIX in SAS v. 9.4; SAS Inst. Inc., Cary, NC) with backward variable selection was used to develop a statistical model exploring risk factors which may contribute to traumatic events and/or carcass bruising. The experimental unit for evaluation of traumatic events was trailer load. Breed (classified as either Holstein cattle or beef breeds), sex, distance traveled, and trailer type ("fat/feeder combination" vs. "fat" trailer) were used as independent variables, or fixed effects, when developing a model to investigate factors contributing to traumatic event prevalence. The experimental unit for evaluation of carcass bruising was lot. When carcass bruise prevalence within each lot was used as

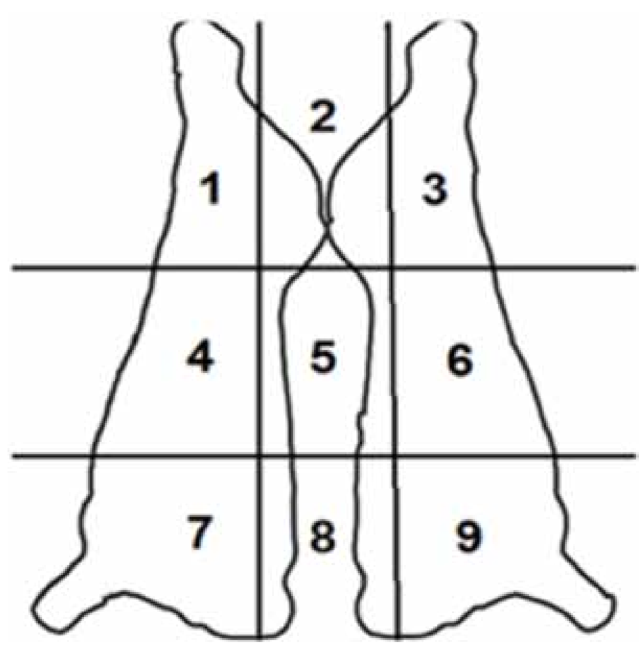

Figure 1. Grid of sections used in the Harvest Audit Bruise Scoring System.

the dependent variable, breed, sex, distance traveled, traumatic event prevalence, ribeye area, fat thickness, yield grade, and average carcass weight were considered independent variables. In both models, slaughter facility and feedyard nested within slaughter facility were considered random effects.

Each analysis started with exploration of frequency distributions, raw means, and other patterns in the data. The GLIMMIX procedure in SAS was used to develop univariable linear regression models for each independent variable to explore linear relationships between the dependent and independent variables. Then, using the GLIMMIX procedure, a full multivariable linear model containing all predictor variables was used to estimate effects on the outcome of interest (traumatic event prevalence or carcass bruising prevalence). Using backward selection, independent variables and their 2-way interactions were eliminated from the model one by one, using a P-value of ≥ 0.05 as exclusion criteria, starting with interactions displaying the highest P-value, then moving to individual variables displaying P-values over 0.05. Forward selection was used to confirm the results of models developed from the backward selection process.

Linear regression was used rather than logistic regression as the data were normally distributed, with seemingly equal variance among the residual errors. In addition, such data must be easily interpreted by industry personnel such as slaughter facility employees, truck drivers, and other personnel involved in the movement of animals from feed-yards to slaughter facilities.

Chi-square goodness of fit tests were used to determine differences of observed versus expected values of carcass bruising by location on the carcass and bruise size. Expected values consisted of equal distribution of bruising on the left side, the right side, and the dorsal midline of the carcass; the cranial, middle, and caudal thirds of the carcass; and small, medium, and large bruises.

Table 1. Description of cattle hauled in each trailer type (fat vs. combination trailers)

Descriptor	Class of cattle	Fat Trailers[1]	Combination Trailers[1]
Number of trailers observed		129	146
Breed			
	Beef	99	132
	Holstein	30	14
Sex			
	Steers	104	108
	Heifers	18	26
	Mixed[2]	7	11
	Not specified		1
Average #head/trailer			
	Beef	34	37
	Holstein	33	37

[1]Fat/feeder combo trailers are those which are used to haul both feeder calves and finished beef cattle. Fat trailers are usually used to haul finished cattle only. The differences between these types of trailers include the presence or absence of a "jail" or "doghouse" in the upper rear compartment of the trailer, used to contain very small calves (present in fat/feeder combo trailers, Beef Quality Assurance, 2006), the presence of a small compartment in the nose of the trailer, used as a counter-balance (also present in fat/feeder combo trailers), and the clearance height of the entrance into the "belly", or lower compartment of the trailer (approximately 2 to 3 inches shorter in fat/feeder combo trailers). Either type of trailer can have a slide-in or fold-up ramp leading into the upper deck compartment.

[2]Mixed lot refers to a lot comprised of both heifers and steers.

Table 2. Description of lots observed for both traumatic events and carcass bruising

Descriptor	Class of cattle	Count
Total Number of lots		75
Average #head/lot		131
Breed		
	Beef	63
	Holstein	12
Sex		
	Steer	54
	Heifer	13
	Mixed[1]	8

[1]Mixed lot refers to a lot comprised of both heifers and steers.

RESULTS

A total of 9,860 animals in 75 lots were observed at 3 different slaughter facilities in the United States. Animals were observed disembarking from 275 trailers. Combination trailers were more frequently observed than fat trailers. The average number of animals hauled in combination trailers was 37 head, and the average number of animals hauled in fat trailers was 33 head (Table 1). The average number of cattle per lot was 131. More lots comprised of beef breeds were observed than Holstein, and there were more lots made up of steers than lots of heifers and/or mixed sex (Table 2). Along with traumatic event and carcass bruise prevalence, a description of carcass data, including average hot carcass weight (kg), average ribeye area (REA), average fat thickness (in), and yield grade by lot is presented in Table 3.

Traumatic Events

Average traumatic event prevalence in finished cattle by lot was 20.4% (± 1.11%, Table 3). When the multiple linear regression model was developed for the outcome of prevalence of traumatic events, an interaction between breed and trailer type (Fig. 2, $P \leq$

Table 3. Description of lots, including carcass characteristics, prevalence of traumatic events experienced, and prevalence of carcass bruising

Breed	Sex	Number of lots, n	Average Carcass Weight, kg, SEM	Average REA[1], in, SEM	Average Fat Thickness, in, SEM	Average YG[2], SEM	Prevalence of Traumatic Events[3], SEM	Prevalence of Carcass Bruising[4], SEM
Beef								
	Heifer	13	371.01 (+ 6.5)	14.09 (+ 0.28)	0.51 (+ 0.02)	2.62 (+ 0.08)	17.2% (+ 3.0%)	67.1% (+ 2.8%)
	Mixed[5]	8	375.0 (+ 5.7)	14.01 (+ 0.23)	0.56 (+ 0.02)	2.73 (+ 0.10)	18.4% (+ 2.9%)	64.9% (+ 3.5%)
	Steer	42	419.2 (+ 4.1)	14.12 (+ 0.17)	0.56 (+ 0.02)	2.65 (+ 0.07)	19.5% (+ 1.4%)	66.7% (+ 1.4%)
	Total	63	403.7 (+ 3.1)	14.1 (+ 0.13)	0.55 (+ 0.03)	2.66 (+ 0.08)	18.9% (+ 1.1%)	66.6% (+ 2.5%)
Holstein								
	Steer	12	394.6 (+ 4.2)	13.85 (+ 0.32)	0.57 (+ 0.01)	2.81 (+ 0.05)	28.6% (+ 2.5%)	76.6% (+ 1.2%)
Total		75	402.2 (+ 3.6)	14.05 (± 0.12)	0.55 (+ 0.01)	2.68 (+ 0.04)	20.4% (+ 1.1%)	68.2% (+ 1.2%)

[1]REA = Ribeye area.

[2]YG = Yield grade.

[3]Prevalence of traumatic event occurrence was calculated dividing the number of traumatic events observed at unloading by the total number of cattle in the trailer.

[4]Prevalence of carcass bruising was calculated by dividing the number of carcasses with a bruise present over the total number of animals in the lot.

[5]Mixed lot refers to a lot comprised of both heifers and steers.

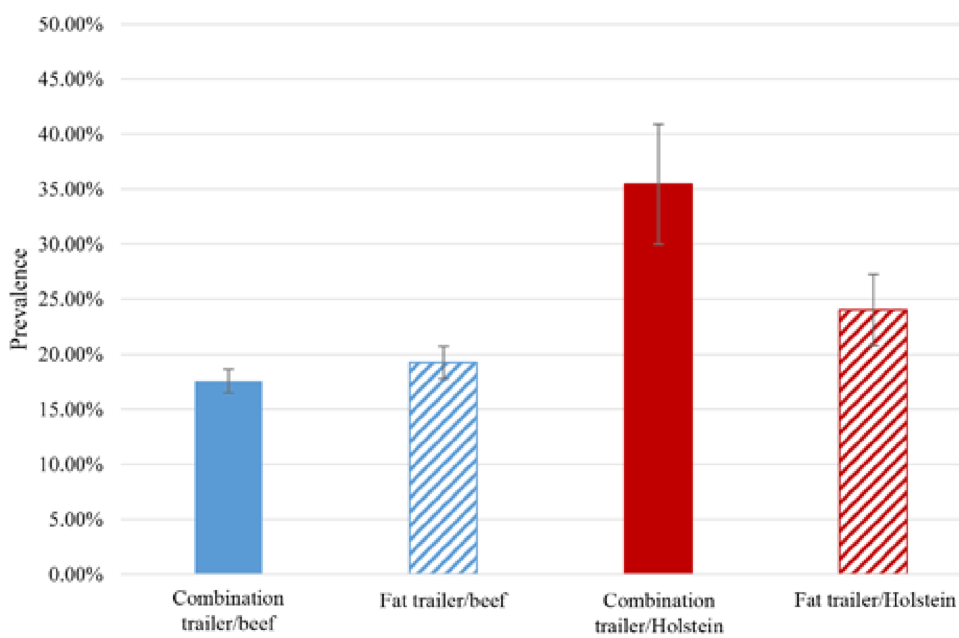

Figure 2. Prevalence of traumatic events for each combination of breed and trailer type. There was a significant interaction between trailer type and cattle breed, whereby Holstein cattle hauled in fat/feeder combination trailers experienced higher prevalence of traumatic events than their beef counterparts. [1]Fat/feeder combo trailers are those which are used to haul both feeder calves and finished beef cattle. Fat trailers are usually used to haul finished cattle only. The differences between these types of trailers include the presence or absence of a "jail" or "doghouse" in the upper rear compartment of the trailer, used to contain very small calves (present in fat/feeder combo trailers, Beef Quality Assurance, 2006), the presence of a small compartment in the nose of the trailer, used as a counter-balance (also present in fat/feeder combo trailers), and the clearance height of the entrance into the "belly", or lower compartment of the trailer (approximately 5–8cm shorter in fat/feeder combo trailers). Either type of trailer can have a slide-in or fold-up ramp leading into the upper deck compartment.

0.05) was observed with traumatic event prevalence being greatest for Holstein cattle hauled in fat/feeder combination trailers. No other risk factors measured were found to be associated with traumatic event prevalence in cattle during unloading at the slaughter facilities (Table 4).

Carcass Bruising

Average carcass bruise prevalence in finished cattle by lot was 68.2% (± 1.15%, Table 3). Prevalence of carcass bruising in beef breed cattle was 66.6%, compared to a prevalence of 76.6% in Holstein cattle (Table 3, $P \leq 0.05$). Over half of the bruises on the beef carcasses ob-

Table 4. *P*-values generated from univariable and multivariable analyses for the outcome traumatic events. Only 2-way interactions were evaluated in the multivariable analysis. Interaction effects are listed in the order by which they were removed from the model using backward selection at a threshold of $P > 0.05$

Independent variable	Univariable *P*-values	Multivariable *P*-values	Final model *P*-values
Distance	0.7026	0.4542	N/A
Sex[1]	0.0091	0.1159	N/A
Breed[2]	0.0001	0.0042	0.0042
Trailer Type[3]	0.0591	0.0507	0.0507
Sex × Trailer	N/A	0.8501	N/A
Distance × Trailer	N/A	0.6945	N/A
Distance × Sex	N/A	0.2727	N/A
Distance × Breed	N/A	0.0713	N/A
Breed × Trailer	N/A	0.0111	0.0111

[1]Sex was categorized as “Steer,” “Heifer,” or “Mixed.”

[2]Breed was categorized as “Beef” or “Holstein.”

[3]Fat/feeder combo trailers are those which are used to haul both feeder calves and finished beef cattle. Fat trailers are usually used to haul finished cattle only. The differences between these types of trailers include the presence or absence of a “jail” or “doghouse” in the upper rear compartment of the trailer, used to contain very small calves (present in fat/feeder combo trailers, Beef Quality Assurance, 2006), the presence of a small compartment in the nose of the trailer, used as a counter-balance (also present in fat/feeder combo trailers), and the clearance height of the entrance into the “belly”, or lower compartment of the trailer (approximately 2 to 3 inches shorter in fat/feeder combo trailers). Either type of trailer can have a slide-in or fold-up ramp leading into the upper deck compartment.

served occurred along the dorsal midline (53.5 ± 1.12%, Table 5, $P \leq 0.05$), which is in agreement with previous research using the Harvest Audit Program Bruise Scoring system and the 2011 National Beef Quality Audit (McKeith et al., 2012; Youngers et al., 2016,). Carcass bruising was greatest in the middle third of the carcass, followed by the cranial third, then the caudal third, which is also in agreement with Youngers et al. (2016, Table 6, $P \leq 0.05$). More medium-sized bruises were observed on the carcasses than small or large bruises (Table 7, $P \leq 0.05$).

When carcass bruising was considered the dependent variable, no interactions were observed. However, breed and average carcass weight were associated with bruising of cattle carcasses (Table 8). Holstein cattle displayed greater carcass bruising than did beef breeds (Table 9, $P \leq 0.05$). As average carcass weight increased, the prevalence of carcass bruising decreased linearly (Fig. 3, $P \leq 0.05$). *P*-values for all univariable and multivariable analyses for the outcome of carcass bruising are listed in Table 10.

Table 5. Percent of carcass bruising on the left side, the dorsal midline, and the right side of beef carcasses. Equal distribution between all regions was expected

Bruise location	Mean, %	SEM, %
Left[1]	26.46[a]	1.10
Midline[2]	53.52[b]	1.12
Right[3]	19.98[c]	1.04

[a–c]Superscripts indicate a significant difference between the observed values and the expected values of the bruising in each region ($P \leq 0.05$).

[1]Bruises along the left side of the carcass were those which occurred in areas 3, 6, and 9 (see Fig. 1).

[2]Bruises along the left side of the carcass were those which occurred in areas 2, 5, and 8 (see Fig. 1).

[3]Bruises along the left side of the carcass were those which occurred in areas 1, 4, and 7 (see Fig. 1).

Table 6. Percent of carcass bruising on the front, middle, and rear thirds of beef carcasses. Equal distribution between all regions was expected

Bruise location	Mean, %	SEM, %
Front[1]	31.30[a]	1.05
Middle[2]	56.13[b]	1.02
Rear[3]	12.57[c]	0.71

[a–c]Superscripts indicate a significant difference between the observed values and the expected values of the bruising in each region ($P \leq 0.05$).

[1]Bruises along the front third of the carcass were those which occurred in areas 7, 8, and 9 (see Fig. 1).

[2]Bruises along the middle third of the carcass were those which occurred in areas 4, 5, and 6 (see Fig. 1).

[3]Bruises along the rear third of the carcass were those which occurred in areas 1, 2, and 3 (see Fig. 1).

Table 7. Percent of carcass bruising categorized as small, medium, or large bruises. Equal distribution between all sizes was expected

Bruise size	Mean, %	SEM, %
Small (< 5cm)	28.64[a]	1.32
Medium (5 to 15cm)	41.77[b]	0.97
Large (> 15cm)	29.58[c]	1.81

[a-c]Superscripts indicate a significant difference between the observed values and the expected values of bruise size.

Table 8. Estimates of parameters for the fixed effects of average carcass weight and breed of cattle assessed with multiple linear regression

Effect	Class[1]	Estimate[2]	SEM	*P*-value
Intercept		1.0952	0.1447	< 0.001
Average Carcass Weight		–0.00082	0.00035	0.022
Breed	Beef	–0.9515	0.03519	0.009
	Holstein	Ref.[3]		

[1]Refers to breed of cattle.

[2]Parameter estimates.

[3]Ref. = reference category.

Table 9. Estimate of mean carcass bruise prevalence per lot by breed (cattle were categorized as either Holstein or beef breeds). Estimates with different superscripts differ significantly ($P \leq 0.05$)

Class[1]	Estimate, %	SEM, %
Beef	67.20[a]	3.0
Holstein	76.70[b]	4.3

[a,b]Superscripts indicate a significant difference between the mean estimates.
[1]Refers to breed of cattle.

DISCUSSION

Traumatic Events

An interaction was observed between breed and trailer type when traumatic events were used as the dependent variable. In the United States, trailer types are usually observed as "fat/feeder combination (combo)" trailers, and "fat" trailers. In other countries, such as Colombia, studies have been conducted exploring the effect of transport vehicle on carcass bruising (Romero et al., 2013). However, the trucks and trailers used in other countries differ greatly from those used in the United States. In most cases, they are smaller, holding only 14 to 16 animals, with open sides and canvas roofing—vastly different from the large aluminum trailers used to haul 30–40 animals at a time in the United States. In the current study, trailer type was defined by the truck drivers hauling the cattle enrolled. Fat/feeder combo trailers are those which are used to haul both feeder calves and finished beef cattle. Fat trailers are usually used to haul finished cattle only. The differences between these types of trailers include the presence or absence of a "jail" or "doghouse" in the upper rear compartment of the trailer, used to contain very small calves (present in fat/feeder combo trailers, Beef Quality Assurance, 2006), the presence of a small compartment in the nose of the trailer, used as a counter-balance (also present in fat/feeder combo trailers), and the clearance height of the entrance into the "belly", or lower compartment of the trailer (approximately 5 to 8 cm shorter in fat/feeder combo trailers). Either type of trailer can have a slide-in or fold-up ramp leading into the upper deck compartment—ramp type was not part of the data collected in this study.

Holsteins experienced more traumatic events compared to beef breeds when hauled in fat/feeder combination trailers than when hauled in trailers for fat cattle only. Dairy breeds, particularly Holsteins, often display larger frame sizes than their beef breed counterparts (Long et al., 1979; Tatum et al., 1986). Therefore, this difference could be due to the decreased space allowance and clearance in the different trailer types and larger frame size of Holstein cattle. Data on frame size would help to make more solid conclusions about the effect height of cattle on traumatic events experienced. Hip height would be a measure which could influence the trauma experienced in different types of trailers, as taller cattle may be more likely to experience trauma and subsequent bruising.

Carcass Bruising

It is generally accepted that animals which experience traumatic events will subsequently display bruising, however the contribution of each traumatic event to the actual bruising displayed is not well documented (Stedman, 2006; Strappini et al., 2013). The correlation between traumatic events and bruising was

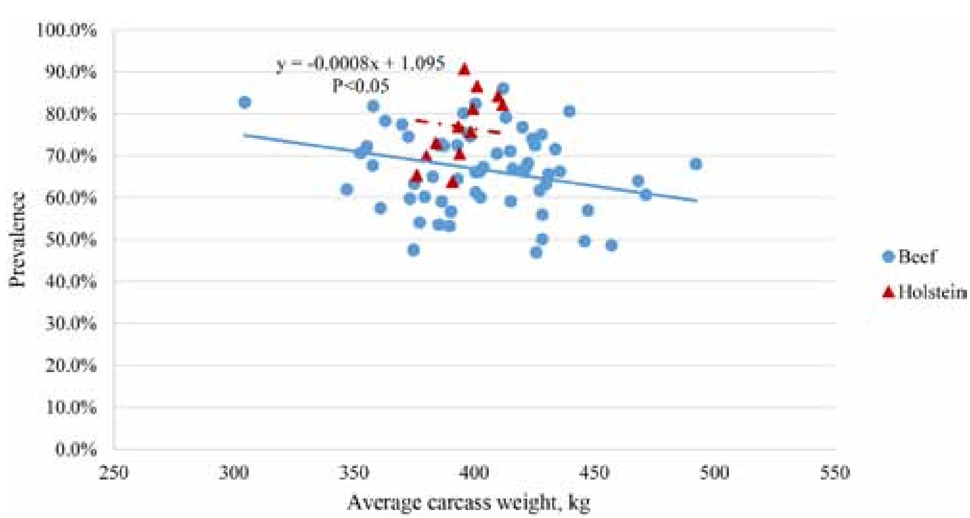

Figure 3. Relationship between average carcass weight and carcass bruising prevalence by lot for lots of Holstein and beef breed cattle ($P \leq 0.05$), results from multivariable linear regression model. Each point on the graph represents a lot of cattle observed. Triangles represent lots of Holstein cattle ($n = 12$), while dots represent lots of beef breed cattle ($n = 63$).

Table 10. *P*-values generated from univariable and multivariable analyses for the outcome carcass bruising. Only 2-way interactions were evaluated in the multivariable analysis. Interaction effects are listed in the order by which they were removed from the model using backward selection at a threshold of $P > 0.05$

Independent variable	Univariable *P*-value	Multivariable *P*-value	Final model *P*-value
Traumatic Events	0.1158	0.3155	N/A
Average Carcass Weight	0.0195	0.0222	0.0222
Distance	0.2169	0.4166	N/A
Sex[1]	0.747	0.5208	N/A
Breed[2]	0.0078	0.0.0087	0.0087
Ribeye Area[3]	0.2375	0.1019	N/A
Average Yield Grade[4]	0.0786	0.4627	N/A
Fat Thickness	0.3968	0.5064	N/A
Traumatic Events × REA	N/A	0.9543	N/A
Traumatic Events × Fat Thickness	N/A	0.8967	N/A
REA × Distance	N/A	0.8023	N/A
Average Carcass Weight × Distance	N/A	0.8797	N/A
Traumatic Events × Distance	N/A	0.8359	N/A
Distance × Breed	N/A	0.6229	N/A
Fat Thickness × Average YG	N/A	0.5394	N/A
Average YG × Distance	N/A	0.3544	N/A
Fat Thickness × Distance	N/A	0.7798	N/A
Average Carcass Weight × Breed	N/A	0.4482	N/A
Traumatic Events × Average Carcass Weight	N/A	0.3222	N/A
REA × Average YG	N/A	0.3068	N/A
Average YG × Breed	N/A	0.1105	N/A
Average Carcass Weight × REA	N/A	0.1875	N/A
Traumatic Events × Breed	N/A	0.2778	N/A
REA × Breed	N/A	0.8703	N/A
Average Carcass Weight × Average YG	N/A	0.1413	N/A
Average Carcass Weight × Fat Thickness	N/A	0.3681	N/A
Fat Thickness × Breed	N/A	0.1259	N/A
Traumatic Events × Average YG	N/A	0.1139	N/A
REA × Fat Thickness	N/A	0.0745	N/A

[1]Sex was categorized as "Steer," "Heifer," or "Mixed."
[2]Breed was categorized as "Beef" or "Holstein."
[3]Ribeye Area = REA.
[4]Yield Grade = YG.

not found to be related in this study. This could possibly be explained due to the fact that traumatic events were only observed at unloading at the slaughter facility. No observations were made at other points where trauma could occur, such as at loading or during the transport process itself. Jarvis et al. (1995b) explored the relationship between the same variables, but found no significant correlation between potentially traumatic events at unloading and the number of bruises per animal. Traumatic events and bruising relationships due to trailer type could not be directly observed in the current study, as cattle in the same lot usually arrived in multiple truckloads. After unloading, these loads were combined back into their original lots and penned together in the slaughter facility holding pens, making it impossible to measure the effect of trailer type on actual carcass bruising in the animals observed.

There was no observed effect of distance traveled on the prevalence of carcass bruising or traumatic events observed in finished cattle. Jarvis et al. (1995a) also found that there was no effect of distance traveled on the bruising scores observed in finished cattle at slaughter. Hoffman et al. (1998) observed that cattle hauled longer distances to slaughter had more bruising on their carcasses than cattle hauled shorter distances. However, that study included mature beef cows, which usually display different physical characteristics than fed cattle, such as less fat cover, and more pronounced bony prominences. The environment in which these studies were conducted must be considered, as the current study focused on fed cattle coming into slaughter facilities which are built relatively close to cattle sources. Jarvis et al. (1995a) included cattle which traveled up to and over 80 miles, but Hoffman et al. (1998) included cattle which had traveled over 580 miles. In the current study, no cattle observed had traveled over 300 miles, and it could be that cattle traveling well over the distances observed here could display higher carcass bruising. In addition, the sources of the cows were different than the sources of the fed cattle observed here, in that the cows used by Hoffman et al. came from ranches and livestock auctions, where the cattle observed here came directly from the feedlot. Movement through livestock auctions could have contributed to carcass bruising in the cows.

In this study, there was no statistical difference between bruising observed in animals of different sexes. Previous research has found sex to be a significant contributor to the carcass bruising observed at slaughter (Romero et al., 2013; Leach, 1982). Research from Romero et al. (2013) indicated that carcass bruising was significantly different between males and females, with males displaying more carcass bruising than females. Another study found that male cattle are more likely to display higher serum creatine kinase (CK) levels, which the authors link to stress and bruising (Mpakama et al., 2014). This difference in CK levels has been documented in humans as well, and is attributed to larger body mass in males (Brancaccio et al., 2007). However, Leach (1982) reported that the occurrence of bruised tissue from cull cows was significantly higher than that of steers. Again, animal type and origin must be considered when comparing results of such studies, as many bruising studies involve a mixture of fed steers and heifers, cull cows, and cull bulls. Such variation in animal type and source was not observed here, as all cattle were sourced from feedyards with the sole intent of being slaughtered as fed beef.

Results show that average carcass weight was significantly correlated with carcass bruise prevalence. Intuitively, one may think that bruising would increase as carcass weight increased, as there may be increased risk of trauma, however the opposite effect was observed. As average carcass weight of the lots increased, carcass bruise prevalence decreased. Some researchers hypothesized that a decrease in fat cover will lead to increased bruising, as the fatty tissue offers some protection from the effects of outside trauma however did not explore the idea extensively (Knowles et al., 1994; Strappini et al., 2012). Strappini et al. (2010) did explore this relationship, and confirmed that as fat cover increased, carcass bruising decreased. Due to the decreased vascularity of fat, it could be that animals experienced similar events which may cause bruising, but the fatty tissue did not hemorrhage as much as the highly vascular muscle tissue in lighter-weight animals.

It may be that heavier cattle may move slower than lighter ones, decreasing the pressure at which potentially traumatic events would occur, which may in turn decrease the potential for carcass bruising. As stated previously, speed of cattle exiting the trucks was not measured in this study. Grandin (1997) indicated that more temperamental or excitable cattle will move faster and are more prone to injury, however bruising was not assessed in that review. Fordyce et al. (1985) reported that temperament had no effect on carcass bruising, but the cattle used in the study were reported to be "relatively quiet." A method to measure flight speed was proposed by Vetters et al. (2013) to determine speed of cattle at processing, and could potentially be used to determine if speed at loading or unloading has an effect on traumatic events or carcass bruising in fed cattle. To better understand how differences in temperament can affect carcass bruising, temperament scores, handling techniques, and speed at which cattle are moved were not recorded in the current study, but could contribute to carcass bruising, and should be assessed when considering trauma and carcass bruising outcomes.

Holsteins displayed more carcass bruising than beef breeds. Dairy breeds, particularly Holsteins, often display larger frame sizes than their beef breed counterparts (Tatum et al., 1986). Research shows that in feeder cattle, frame size has a significant effect on carcass weight, where larger frame size leads to higher carcass weight (Dolezal et al., 1993). An interaction between breed and average carcass weight would better support such a hypothesis. Since frame size or hip height were not measured in this study, it is impossible to conclude the effect of frame size on carcass bruise prevalence. Mpakama et al. (2014) reported on the association of breed with creatine kinase levels, but did not report on the relationship between breed and carcass bruising, and did not assess the breeds represented in the current study. In addition, while mature body size is genetically determined, research shows that it can be altered by nutritional or hormonal factors, including malnutrition and hormonal growth implant status (Owens et al., 1993). In this study, the number of Holstein animals observed compared to the number of beef animals could contribute to the lack of a statistically significant interaction between breed and average carcass weight. More data should be collected to determine how frame size, as measured by hip height or a frame score, affects bruising in both beef and Holstein cattle.

Conclusion

While there are limitations to this and many other observational studies, the information gleaned here can contribute to an existing knowledge base. Here, Holstein cattle hauled in trailers with smaller dimensions experienced more traumatic events than when hauled on larger trailers. Holstein cattle also displayed a higher prevalence of carcass bruising than cattle of beef breeds, and bruising decreased in both breeds as hot carcass weight increased. More research is needed to better understand how the entire transportation process, including animal handling at loading and unloading, trailer type, and animal risk factors contribute to carcass bruising in fed cattle. Risk factors such as breed, sex, cattle temperament, and carcass traits should not be overlooked. In addition, the type of cattle being observed must be considered, and comparisons between groups should be made with caution, always remembering that risk factors can differ between the groups. However, no matter what cattle group or type is included in subsequent research, carcass bruising in cattle is a significant economic and animal welfare issue, and only more research can help decrease the number of animals which experience trauma during the transport process and carcass bruising at slaughter.

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