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Is it possible to produce good quality meat from Holstein-Friesian bulls?

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Abstract

There is potential to increase the value of meat from Holstein-Friesian bulls by increasing the proportion of carcasses that are of suitable quality to be eligible for primal cuts sold in high-value markets. The objective of this study was to explore relationships between carcass and meat-quality traits from Holstein-Friesian bulls between 21-38 months of age, slaughtered on different occasions. Meat samples of *M. longissimus lumborum* were collected at slaughter and chill-aged at -1.5ºC for seven days. The means (±s.d.) were: carcass weight 313±29 kg (n=256), dressing-out 54.7±2.6% (n=256), ultimate pH 5.9±0.38 (n=221), shear force 11.34±4.93 kgF (n=221), cook loss 28.4±5.4% (n=220) and colour indexes (n=159) L* (lightness) 36.06±2.96, a* (redness) 12.38±4.04 and b* (yellowness) 8.74±2.24. A total of 80 samples (36%) were found to be both of acceptable tenderness (below 10.9 kgF) and pH less than 5.8. Alleviating meat pH issues is required to ensure high-quality meat from bulls that is suitable for high-value primal cuts.

Keywords: bull; meat; dark-cutting; lean beef

Introduction

Meat sourced from New Zealand bulls is mainly low-value ‘processing’ or grinding beef (Peden 2008). Bulls grow faster and are heavier than steers at the same age, produce larger steaks because they are better muscled and have about a third of the intramuscular fat content (Purchas 1990). However, beef from bulls is often less tender than that of steers. This has been attributed to higher ultimate pH, shorter sarcomere length, lower proteolytic activity, lower levels of intramuscular fat, variable cooking losses and water-holding capacity, and possibly a greater contribution of connective tissue components (Purchas 1990; Purchas & Aungsupakorn 1993; Purchas et al. 2002). Bulls also produce darker meat with lower reflectance values as a consequence of high pH (Purchas 1990). This high incidence of unacceptable meat quality means that the majority of the carcass meat is destined for grinding beef, such is used to produce hamburger patties.

There is potential to increase the value of meat from Holstein-Friesian bulls by increasing the proportion of carcasses that are of suitable quality to be eligible for primal cuts sold in high-value markets, such as eye fillet, sirloin and ribeye. Some high-value markets prefer leaner beef rather than highly marbled beef (Julie McDade, personal communication), but it still needs to have acceptable eating quality, particularly in terms of tenderness and appearance (Miller et al. 2001; Verbeke et al. 2010).

Meat-quality measurements from bulls have shown variable results, and explanations for the basis of the variability would be of value when seeking ways to produce beef of consistently high quality from bulls (Purchas et al. 2002). The objective of this study was to explore relationships between carcass and meat-quality traits from Holstein-Friesian bulls between 21-38 months of age, slaughtered on different occasions.

Materials and methods

Animals

Holstein-Friesian bulls born in 2013 (n=84, autumn n=36, spring=45, unknown=3), 2014 (n=84, autumn n=58, spring=20, unknown=6) and 2015 (n=88, autumn n=69, spring=17, unknown=2) were purchased by Taniwha Farm (Waerenga, New Zealand) at around 12-16 weeks of age (~100 kg). Dates of birth were unknown, but for this analysis were assumed to be 1st April for autumn-born and 1st September for spring-born bulls. Bulls were managed under commercial pastoral farming conditions until finishing at a mean (±s.d.) 28±3 months of age and 573±42 kg live weight. Bulls were sent to slaughter in groups of 8 to 36 animals, at the farmer’s discretion. The bulls were taken off pasture 1-2 hours prior to transporting, were transported for 0.5-1 hour by truck, and were slaughtered within 3 hours of arriving at the plant. No mixing of grazing groups bulls occurred on farm and no mixing with bulls from other farms occurred at the plant.

Slaughter and meat sample collection

A total of 256 bulls were slaughtered at Greenlea Premier Meats Ltd (Hamilton and Morrisville plants) between November 2015 and November 2017 in 16 different groups. Slaughter and dressing were undertaken according to standard New Zealand industry practice. Bulls were electrically stunned prior to exsanguination on an immobilisation table before dressing and fabrication (hot boning). On the day of slaughter, live and carcass weights were measured at the plant, and dressing-out percentage (DO%) calculated as 100 x (carcass weight/live weight). At approximately 35 minutes post mortem, a ~500 g sample of *Longissimus lumborum* muscle excised from the region spanning the 13th -14th vertebrae was recovered from each carcass, vacuum packaged and transported in a chilly-bin with ice packs to AgResearch Ruakura (Hamilton, New Zealand) for chill-aging and meat-quality analyses.

Laboratory methods

Muscle samples were chill-aged at -1.5°C from approximately 2 hours post mortem, for seven days before freezing at −18°C. A total of 221 samples (in batches of 12 samples) were thawed overnight at 4ºC, to undertake the meat-quality measures. The pH was recorded using a Hanna 99163 pH meter with a FC232D combined pH/temperature probe (Hanna Instruments, Rhode Island, USA). The probe was directly inserted into the sides of each loin sample after opening.

For colour measurements (n=159), a ~20 mm slice from the anterior end of the sample was taken and placed in an over-wrapped tray under simulated retail lighting conditions at 4°C. Colour measurements of lightness (L*), redness (a*) and yellowness (b*) were taken on the surface of the over-wrapped meat at seven days post mortem, using a calibrated Minolta Colour Meter (Illuminant D65, 1 cm diameter aperture, 10° standard observer; CR-300; Konica Minolta Photo Imaging Inc., Tokyo, Japan).

For tenderness assessment, a 25 mm thick steak was prepared from each *Longissimus lumborum* sample. The pre-cook weight of each steak was recorded and each steak was cooked individually in a plastic bag immersed in a water bath set at 99°C until an internal temperature of 75°C was reached. The cooking temperature was monitored using a thermocouple positioned at the centre of the sample and attached to a Digi-Sense scanning temperature logger (Eutech Instruments Pte Ltd., Singapore). Once the samples reached 75°C, they were immediately cooled to 10°C in ice-water slurry. After cooking and cooling, each cut surface was blotted with paper towels and the steak was reweighed to determine the loss in weight. Cooking loss was calculated as the difference between pre-cooked and cooked weight, expressed as a percentage of the uncooked weight.

Shear force was measured as described by Chrystall and Devine (1991). Between eight and 10 subsamples ~25 mm long with a 10 mm × 10 mm cross sectional area were prepared from each cooked steak, using a double-bladed scalpel with blades set 10 mm apart in such a way that the long axis was parallel to the muscle fibre orientation. Shear force was measured in kPa using a MIRINZ Tenderometer (MIRINZ Inc., Hamilton, New Zealand) and converted to kgF using the formula kgF = kPa x A + B (where the coefficients A and B depend on calibration of the equipment). The final shear force (kgF) to cut across the fibres was calculated as the mean of the sub-samples prepared from each steak.

Statistical analysis

Data were analysed using SAS v9.4 (SAS Institute Inc., Cary, NC, USA). Raw means were calculated for pre-slaughter live weight, carcass weight and DO%. Linear models were used to analyse pH, shear force, cook loss and colour parameters (L*, a* and b* at seven days post mortem). Season of birth and slaughter group were fitted as fixed effects, and carcass weight and pH were fitted as covariates for shear force, cook loss and colour parameters. The model for shear force included pH as a quadratic effect. Slaughter age was not fitted in the models as it was confounded with slaughter group. Further, a second analysis was conducted in which pH was divided into two classes (<6 and ≥6) to analyse colour parameters, and into three classes (<5.8, 5.8-6.2 and >6.2) to analyse shear force, and pH class was fitted as a fixed effect for these analyses.

Results and discussion

Carcass and meat-quality trait means are presented in Table 1. Carcass weight and DO% were just above New Zealand national averages for bull production from 2012 (306 kg with 54% DO at 27-34 months of age; Morris 2013). Dressing-out percentage increased with increasing carcass weight (0.06±0.01, P<0.0001) and varied among slaughter groups (P<0.0001). Slaughter group had a significant effect on pH (P<0.0001, Figure 1), and this has been reported previously as handling, transportation, and pre- and post-slaughter conditions contribute to muscle ultimate pH post-mortem (Dixon et al. 1996; McDade 2010; Njisane & Muchenje 2017). It is clear from Figure 1 that some slaughter groups had all bulls with acceptable pH (<5.8) whereas other groups had a high proportion of high pH carcasses. The specific causes contributing to variation in pH among slaughter groups were not able to be determined in this study, but should be a consideration for future investigations.

Ultimate pH affected all meat-quality traits (tenderness, cook loss and colour parameters, P<0.0001, Table 2). There was also a significant effect of slaughter group on all meat quality traits (P<0.05), even when adjusting for pH. Neither pre-slaughter live weight nor carcass weight affected pH, tenderness or colour parameters (P>0.05).

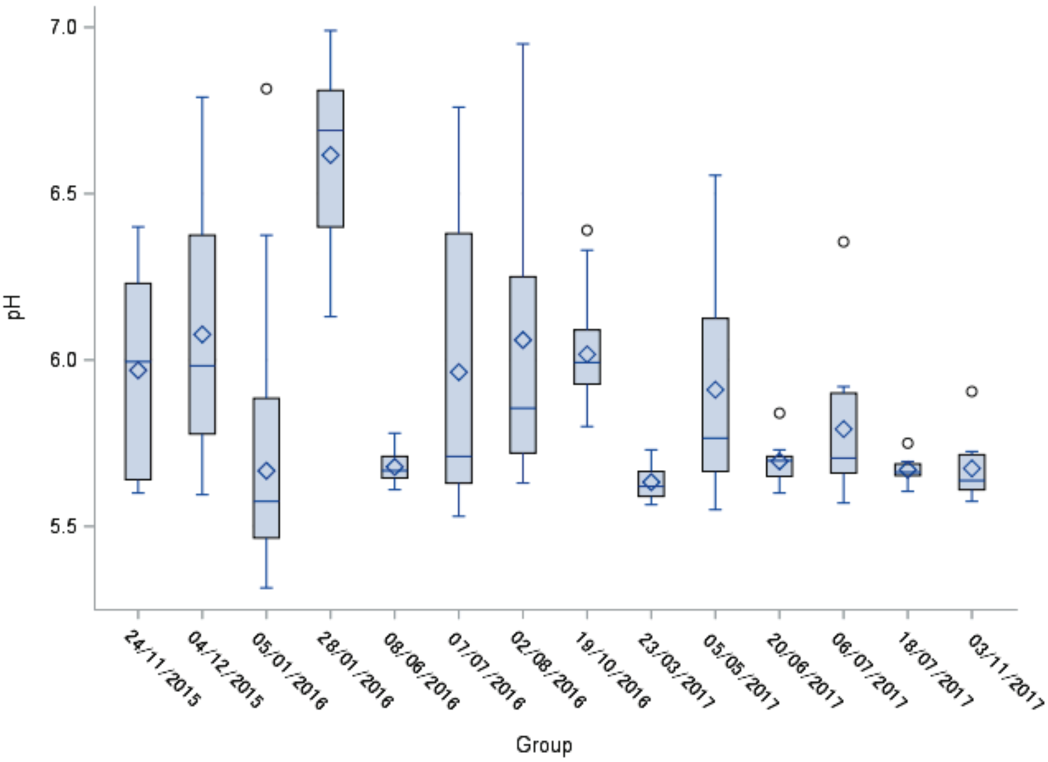
As expected, pH had impacts on several meat-quality traits of the bull's *Longissimus lumborum* muscle. Meat samples with pH above 6 (n=64, 29% of bulls) were darker and had lower cooking losses than did meat samples with pH below 6 (P<0.05). This meat is commercially known as DFD (dark, firm and dry) or dark-cutting meat (Tarrant & Sherington 1980). Typically, this type of meat is not suitable for traditional high-value primal cuts, such as eye fillet, sirloin and ribeye. Nevertheless, due to the functional attributes of high pH beef, such as high water-holding capacity (Huff-Lonergan & Lonergan 2005) and increased digestibility with pH above 6.2, this lean bull beef could be used by the meat industry to produce nutritious meat products for different market segments (e.g., aged care, where maintaining protein intake is a challenge; Farouk et at. 2014), other than grinding beef.

Tough meat samples with shear force greater than 10.9 kgF (Bickerstaffe et al. 2001) were found across a wide pH range. However, greatest shear force values (indicating toughest meat) were found in samples with pH between 5.8 and 6.2 (n=52, 24% of bulls) compared with meat with

Table 1 Means (±s.d.) of age and weight at slaughter, carcass weight, dressing-out percent, together with ultimate pH, shear force, cooking loss and colour indexes (lightness (L*), redness (a*) and yellowness (b*) at day 7 post-mortem), from meat samples from the *Longissimus lumborum* muscle of Holstein-Friesian bulls slaughtered in 16 different groups.

Variable	n	Age (months)	Slaughter weight (kg)	Carcass weight (kg)	Dressing-out (%)	Ultimate meat pH	Shear force (kgF)	Cook loss (%)	Colour parameters at day 7		
									L*	a*	b*
n		245	256	256	256	221	221	220	159	159	159
Mean±s.d		28±3	573±42	313±29	54.7±2.6	5.90±0.38	11.3±4.9	28.4±5.4	36.1±3.0	12.4±4.0	8.7±2.2
Slaughter group											
24/11/2015	10	31±2	572±15	311±12	54.4±1.3	5.97±0.31	11.3±3.1	28.6±4.7			
04/12/2015	26	30±2	565±28	315±19	55.8±1.7	6.08±0.36	11.8±4.8	26.3±4.0			
05/01/2016	36	28±4	556±22	291±13	52.4±1.4	5.67±0.33	11.6±4.4	31.1±3.6	37.0±2.8	14.8±2.9	7.9±2.0
28/01/2016	16	30±2	483±28	254±17	52.8±4.2	6.62±0.26	7.1±3.7	19.4±4.6	34.0±1.6	3.7±0.8	9.7±1.2
08/06/2016	14	28±4	607±31	320±20	52.7±1.3	5.68±0.05	10.1±3.0	26.8±3.0			
07/07/2016	17	28±3	608±22	348±20	57.3±2.0	5.96±0.44	8.4±3.5	27.3±4.7	34.9±3.3	14.5±4.1	6.8±2.7
02/08/2016	14	28±0	566±30	321±17	56.7±1.5	6.06±0.45	9.7±4.5	25.8±5.2	34.3±2.8	13.8±3.2	6.6±2.3
19/10/2016	24	29±3	612±30	334±20	54.6±1.5	6.02±0.15	18.6±5.0	25.8±4.3	37.4±2.4	10.8±1.4	9.4±0.9
23/03/2017	11	31±2	554±39	302±27	54.4±1.6	5.63±0.05	10.0±2.2	27.9±3.4	37.2±1.5	13.5±1.6	10.4±1.1
05/05/2017	21	25±0	605±17	333±13	54.9±1.3	5.91±0.32	12.2±3.9	30.8±4.4	34.6±3.3	11.9±3.0	9.2±2.2
20/06/2017	10	27±0	583±29	322±26	55.2±2.5	5.70±0.06	13.5±4.7	36.0±2.6	36.5±2.2	13.3±1.3	10.3±1.0
06/07/2017	11	27±1	570±26	314±17	55.1±1.5	5.79±0.22	10.5±3.6	31.4±3.9	38.2±2.6	13.6±2.6	10.5±2.0
18/07/2017	8	28±0	542±20	290±14	53.6±1.2	5.67±0.04	7.7±1.7	32.1±3.6			
03/11/2017	10	30±2	545±16	324±15	59.4±2.3	5.67±0.10	8.9±2.9	33.4±2.9			
23/11/2017	9	31±2	573±44	312±32	54.4±3.0						
13/12/2017	19	29±2	588±37	321±28	54.6±2.3						

Figure 1 Box and whisker plot of the distribution of ultimate pH of meat samples from the *Longissimus lumborum* muscle of Holstein-Friesian bulls (n=221) slaughtered in 14 different groups at 28±3 (s.d.) months old.



higher (n=47, 21% of bulls) or lower pH (n=122, 55% of bulls, P<0.05). This is due to the quadratic relationship between pH and shear force, shown in Figure 2. Several authors have previously reported an increase in shear force from pH 5.4-5.5 to 6-6.2, with maximal toughness around pH 6-6.2, and a decrease in shear force thereafter (Purchas 1990; Purchas & Aungsupakorn 1993; Ertbjerg & Puolanne 2017). Although shear force decreases with pH above 6.2, this high pH is associated with other changes in meat quality (such as texture, taste, colour and shelf life) that

Table 2 Regression coefficients of shear force, cooking loss and colour indexes (lightness (L*), redness (a*) and yellowness (b*) seven days post-mortem) on pH and pH^2, for meat samples from the *Longissimus lumborum* muscle of Holstein-Friesian bulls slaughtered in 14 different groups at 28±3 (s.d.) months old.

Variable		n	pH	P-value	pH^2	P-value
Shear Force (kgF)		221	155.02±22.51	*<0.0001*	-12.88±1.84	*<0.0001*
Cooking Loss (%)		220	-6.58±0.87	*<0.0001*		
Colour						
Day 7	L*	159	-5.21±0.59	*<0.0001*		
	a*	159	-6.82±0.45	*<0.0001*		
	b*	159	-4.89±0.32	*<0.0001*		

makes it less desirable.

A total of 80 samples (36%) were found to be both of acceptable tenderness (below 10.9 kgF, according to the classification by Bickerstaffe et al., 2001) and pH less than 5.8. Meat below pH 5.8 had a bright red colour (higher L*, a* and b* values, compared with meat with pH 5.8 or higher, $P<0.05$, data not shown). The percentage of samples with acceptable tenderness decreased for samples with pH higher than 5.8, and therefore, alleviating meat pH issues is required to increase the yield of high-quality meat from bulls that is suitable to be eligible for high-value primal cuts.

A greater understanding of the relationships among production traits and meat-quality traits for bulls would enable bull-beef value chains to make more informed breeding decisions. Meat quality and consistency in bull beef might be improved by genetic selection, as genetics account for 5-30% of the total phenotypic variance in beef quality traits (Warner et al. 2010). Even though meat ultimate pH is low to moderately (0.06-0.27) heritable (King et al. 2010; Warner et al. 2010), genetic selection of other traits (e.g., stress resilience) could be used to improve beef quality. Further research will evaluate mechanisms for early identification of bulls suitable for producing high-value beef from Holstein-Friesian bulls, including genetic factors, on-farm management and temperament.

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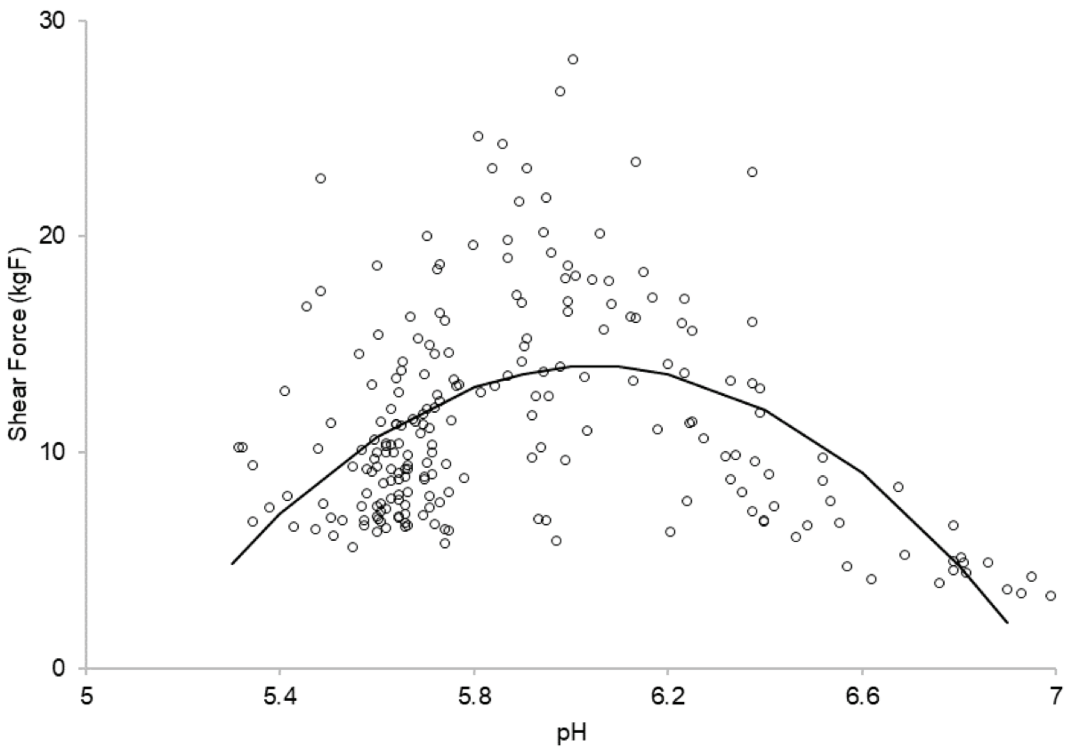
Figure 2 Scatter plot of shear force (kgF) and ultimate pH of meat samples from the *Longissimus lumborum* muscle of Holstein-Friesian bulls (n=221) slaughtered in 14 different groups at 28±3 (s.d.) months old. Quadratic line was fitted as Shear force = $-584 + 197.85*pH - 16.35*pH^2$ ($R^2 = 0.28$).



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