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Relationship between phenotype, carcass characteristics and the incidence of dark cutting in heifers

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ABSTRACT

Previous research has suggested that cattle predisposed to dark cutting can be identified from live animal or carcass characteristics. This hypothesis was tested using production and phenotype data from an existing data set collected from heifers ($n = 467$) on study at three farms. Carcasses in the data set graded Canada AAA ($n = 136$), AA ($n = 296$), A ($n = 14$), and B4 (dark cutting, $n = 21$). Farm was identified as significant ($P = 0.0268$) by CATMOD analysis and slaughter weight and carcass weight accounted for the variation in dark cutting frequency across the farms. Analysis of variance indicated that dark cutting heifers had reduced weight at weaning ($P < 0.0001$) and at slaughter ($P < 0.0001$), and produced reduced weight carcasses ($P < 0.0001$). Results of logistic regression indicated that the probability of dark cutting was decreased in heifers slaughtered at live weight greater than 550 kg and in carcasses weighing greater than 325 kg.

1. Introduction

Carcasses from cattle under 30 months of age that have a purple or dark red rib eye muscle (m. *longissimus thoracis*, LT) at grading are considered dark cutting and graded Canada B4 (Canadian Agricultural Products Act SOR/92-541, 2014), while carcasses with normal rib eye muscle colour are graded by marbling score into Canada Prime, AAA, AA and A, which are equivalent to United States Department of Agriculture (USDA) Prime, Choice, Select and Standard. Dark cutting beef usually has an ultimate pH greater than 5.8 and is discriminated against by retailers because of its reduced shelf life and by consumers because of its abnormally dark appearance. Because of this reduced retail acceptability, dark cutting carcasses are discounted by as much as 40%, resulting in a substantial economic loss to producers whose cattle are affected; therefore identifying dark cutting cattle before slaughter for remediation would be financially advantageous.

Production factors related to dark cutting are manifold and include the use of growth promotants (Schneider, Tatum, Engle, & Bryant, 2007), pre-slaughter management (Lacourt & Tarrant, 1985; Mach, Bach, Velarde, & Devant, 2008), and time of year/season (Knee, Cummins, Walker, & Warner, 2004; Kreikemeier, Unruh, & Eck, 1998). The frequency of dark cutting has also been found to be higher in heifer than in steer carcasses (Lorenzen et al., 1993), likely because of their temperament (Voisenet, Grandin, O'Connor, Tatum, & Deesing, 1997), estrus activity (Kenny & Tarrant, 1988) or reduced carcass weight (Murray, 1989). Relationships between animal and carcass phenotypes and dark cutting incidence have been identified (McGilchrist, Alston, Gardner, Thomson, & Pethick, 2012) but are contentious, as increased carcass weight, fat depth and rib eye area have been associated with reduced incidence of dark cutting (McGilchrist et al., 2012), while increased rib eye area (Hawrysh, Gifford, & Price, 1985; Park, Lee, & Hwang, 2007), animal growth rate (Młynek & Guliński, 2007) and slaughter weight (Vestergaard, Oksbjerg, & Henckel, 2000) have also been associated with increased dark cutting. The relationship between dark cutting and marbling score is also unclear, with increased marbling score either unrelated (McGilchrist et al., 2012) or linked to reduced dark cutting frequency (Park et al., 2007). Similarly, the relationship between dark cutting and muscle fibre type may also be important, as Zerouala and Stickland (1991) found that beef *longissimus dorsi* (LD) at 48 h post-mortem that had colour which was slightly to vividly dark and pH greater than 6.0 had more oxidative and fewer glycolytic fibres compared to normal LD. Earlier, Hunt and Hedrick (1977) reported dark cutting LD had intermediate fibres percentage greater than that of normal beef LD but similar to that of pale, soft and exudative (PSE) LD, suggesting that dark cutting may supersede PSE as the duration of antemortem stress increased and intramuscular glycogen is depleted.

Despite efforts to mitigate the occurrence of dark-cutting such as not mixing unfamiliar cattle, its incidence has increased in Canada within the last 10 years from 0.8 to 1.3% (Beef Cattle Research Council (BCRC), 2013), while in the United States of America (US) the

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proportion of dark-cutting has increased from 1.9% in 2005 (Garcia et al., 2008) to 3.2% in 2012 (Moore et al., 2012). Finishing cattle on a high plane of nutrition appears to confer some resistant to the depletion of muscle glycogen by pre-slaughter stressors (Warner, Walker, Eldridge, & Barnett, 1998), although feed efficient animals may be at risk of dark cutting (Baker et al., 2006). The persistence of dark cutting in the beef industry, despite significant research efforts and implementation of prevention strategies, can be a source of substantial economic loss to cattle owners and makes it worthy of continued research. The purpose of this study was therefore to relate heifer phenotype and carcass conformation to the frequency of dark cutting to test the hypothesis that the likelihood of a heifer producing a dark cutting carcass can be predicted from live measurements.

2. Materials and methods

The study was conducted on an existing data set with production and carcass measurements available; as a result, no animal ethics approval was required. Cattle in the data set were, however, from previous research studies in which they were cared for according to the Canadian Council on Animal Care (CCAC, 1993) guidelines.

2.1. Data

Data from heifers ($n = 467$) with complete live animal and carcass data were used for detailed analysis of the relationships between carcass and production phenotypes and the frequency of dark cutting. Data were collected from cattle on study from 2003 to 2011 on three farms, designated A, B and C, which contributed $n = 44$, $n = 267$, and $n = 156$ heifers, respectively. The carcasses in the data set graded normal Canada AAA ($n = 136$), AA ($n = 296$), and A ($n = 14$) or dark cutting Canada B4 ($n = 21$). Notably, because the dark cutting Canada B4 grade consists of Canada Prime, AAA, AA and A carcasses deemed dark, this grade may contain a range of marbling levels. The heifer data from farm A were previously used for the relationship of dark cutting with gender and production phenotype in that farm (Mahmood, Basarab, Dixon, & Bruce, 2016).

Production and carcass data were as described by Mahmood et al. (2016) and included animal weaning weight (WW, kg), live weight at slaughter (LW, kg), dry matter intake (DMI, kg DM day^{-1}), average daily gain (ADG, kg gain day^{-1}), feed conversion ratio (FCR, kg DMI kg^{-1} gain), residual feed intake adjusted for ultrasound subcutaneous fat depth (RFI_{fat}, kg DMI day^{-1}), ultrasound rib eye area (uREA, cm^2), ultrasound subcutaneous fat depth (uFD, mm), ultrasound marbling score (uMS), hot carcass weight (CW, kg), grade fat depth (gFD, mm), grade rib eye area (gREA, cm^2), and grade marbling score (gMS). The data also included animal age at test (age at the start of feeding concentrate diet), days to finishing (DF; number of days the cattle were fed concentrate diet), and age at slaughter (SA). Live weight at slaughter (kg) was calculated from initial feed trial weight added to the number of DF multiplied by the ADG. Production and phenotypic measurements were performed similarly to that described by López-Campos, Basarab, Baron, Aalhus, and Juárez (2012) and López-Campos, Aalhus, Okine, Baron, and Basarab (2013). Dry matter intake was calculated by multiplying daily feed intake by feed dry matter, with daily feed intake measured using GrowSafe® feeding stations (GrowSafe® System Inc. Airdrie, Alberta, Canada) and feed dry matter estimated from pooled feed samples dried at 80 °C in a forced-air oven to a constant weight. Feed conversion ratio was calculated by dividing average daily dry matter intake by ADG. Residual feed intake was calculated as the deviation of actual feed intake from expected feed intake and adjusted for uFD (Basarab, McCartney, Okine, & Baron, 2007; Basarab et al., 2003). Ultrasound subcutaneous fat depth, uREA and uMS were estimated prior to slaughter using an Aloka 500V diagnostic real-time ultrasound with a 17 cm 3.5 MHz linear array transducer (Overseas Monitor Corporation Ltd, Richmond, BC, Canada) by a certified ultrasound technician as described by Brethour (1992). Ultrasound subcutaneous fat depth, gFD, uMS, gMS, uREA and gREA were measured at the Canadian beef grading site, which is at the 12–13th LT (rib eye) muscle interface. Both uMS and gMS were categorized using the United States Department of Agriculture (USDA) scoring system (USDA, 1997) where Canada A, AA, AAA and Prime quality grade marbling corresponded with traces (Standard, 300–399), slight (Select, 400–499), small to moderate (Choice, 500–799), and greater than or equal to slightly abundant (Prime, 800–1099) amounts of marbling, respectively. Traces, slight, small to moderate and greater than or equal to slightly abundant marbling, respectively which, in turn equated to ultrasound marbling scores between 1.00 to 3.99, 4 to 4.99, 5 to 7.99, and 8 to 11.

The cattle under study were Hereford (sire)-Angus (dam) and purebred Charolais at farm A. Cattle at farms B and C were crossbred composite (BeefBooster®, Calgary, Alberta) that originated from the cross of BeefBooster® terminal composite (TX) sires with crossbred cows (British x British-Continental). BeefBooster® terminal composite bulls (TX) were predominantly Charolais-based with infusion of Holstein, Maine Anjou and Chianina breed (http://www.beefbooster.com). Heifers in the data set were not fed melengestrol acetate (MGA) to control estrous cycle. Cattle from each farm were slaughtered separately in two lots and each lot had data from at least one animal/carcass from each grade. Cattle at farm A were fed and processed at the Agriculture and Agri-Food Canada Meat Research Laboratory (Lacombe, Alberta, Canada) where the distance between feeding and slaughter facility was 3 km. The cattle at farm B and C were fed separately at two commercial feedlots and shipped to a commercial beef abattoir located at a distance of about 85 km and 130 km from farm B and C, respectively. The cattle from all the farms were transported by standard tractor-trailers early morning and slaughtered within 2–5 h after their arrival at slaughter plants. Cattle were neither moved using electric prods nor were the cattle from pens, at any farm, mixed during and post-transportation. Carcasses were not electrical stimulated and were not spray-chilled. The carcasses from animals from all the three farms were split and weighed to record CW and then chilled for 48 h at 2 °C with an average wind speed 1.4 m/s. After chilling, left sides of the carcasses were ribbed at between 12th and 13th ribs for assessment of colour, gFD, gMS, and gREA and quality grade was assigned by certified beef graders. The dark cutting (B4 grade) carcasses were delineated based upon a federally-approved colour standard.

2.2. Statistical analysis

The statistical analyses were performed using the Statistical Analysis Software (SAS) system (Version 9.3, SAS Institute Inc. Cary, NC). A generalized logit model was applied using the CATMOD procedure to compute the frequency of dark cutting in three farms while animal and carcass parameters were tested as covariates. Analyses performed on phenotypic and carcass data included analysis of variance, Pearson correlations, and binomial and multinomial logistic regression. Data were used to examine the effects of farm (A, B, C) and grade (Canada AAA, AA, A and B4) on live animal and carcass characteristics using the MIXED procedure with farm, grade and their interaction as fixed effects and slaughter lot within farm was included as a random term that served as the error term for farm. Kenward-Roger approximation was used to compute the denominator degrees of freedom while differences between means were identified using least square means differences, with significance at $P < 0.05$. For analysis of variance of DMI and ADG, body weight at the start of finishing was included as a covariate. Carcass rib eye areas adjusted (adjusted gREA) for each 45.45 kg of CW was also used for the analysis of variance. Where analysis of variance models were significant ($P < 0.05$), differences between means were identified using least square means differences, with significance at $P < 0.05$.

Relationships between independent variables were investigated using Pearson correlations (PROC CORR) and the Bonferroni correction was used to compensate for the likelihood of type I significance error