RECOVERING VALUE FROM CANADA B4 DARK CUTTING BEEF CARCASSES

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Abstract –The incidence of dark-cutting carcasses has persisted at 1 to 2% despite improved cattle management and represents a significant economic loss as dark carcasses are penalized up to $0.40/kg. Recovering value from these carcasses may be possible as not all muscles in the carcass may be equally affected and may vary with rib muscle pH. Ten normal (Canada AA), 10 classic (rib eye pH > 6.0) and 10 atypical (rib eye pH $\leq$ 5.8) carcass sides were dissected and proportion of dark muscles determined using the Japanese Meat Grading Association colour standards. One-way analysis of variance with grade category as the source of variation. Atypical dark cutters exist within the slaughter population, but do not completely conform to theoretical science relating to muscle pH and colour. The proportion of muscles within grade B4 carcasses that are abnormally dark are related to mean pH values of the rib eye. Grade B4 carcasses within pH categories demonstrate potential for muscle recovery and recommendations based on this study may mitigate future strategies to recover costs.

Key Words – Beef, Colour, Dark firm dry, pH.

I. INTRODUCTION

In Canada, dark cutting carcasses are graded Canada B4 and are penalized from 0.30 to 0.40 $/kg carcass weight. As a result, beef producers lose on average $300 dollars a head for dark cutting carcasses as the whole carcass is downgraded. Recent research [1] suggested that not all muscles of the carcass are compromised by the dark cutting condition, which may mean that additional value could potentially be obtained from Canada B4 carcasses if only a few muscles are affected. Carcasses exhibiting the 'dark-cutting' condition usually arise after cattle experience physical stresses prior to slaughter such that muscle glycogen is depleted. The depletion of muscle glycogen prevents post mortem muscle pH from declining and produces abnormally dark muscles. Mixing cattle that are unfamiliar with each other or transporting cattle just prior to slaughter can also deplete muscle glycogen stores [2, 3], but this phenomenon is usually limited to specific muscles [1]. In fact, Bass et al. [1] found a lack of relatedness between *m. longissimus thoracis* (LT, rib eye) colour and the colour of other muscles while Tarrant and Sherington [4] found that intramuscular pH was more frequently affected in the LT than in other muscles. Also, Wulf et al. [5] indicated that more than one type of dark cutting carcass existed, and that another class of dark cutting carcasses has emerged where the rib eye muscle is dark but the ultimate pH is less than 5.8. This type of 'atypical' dark cutter does not completely conform to the accepted relationship between muscle pH and colour as the rib eye muscles from these carcasses appear to have sufficient glycogen necessary to produce bright red meat but produce dark beef instead. Dark cutting carcasses are recognized in the industry as 1/3, ½ or full degree dark cutting carcasses [1] but whether the class of dark-cutter is related to the extent of dark muscle throughout the carcass is unknown. The hypothesis tested by the current study was that LT ultimate pH is related to the proportion of dark muscle within the remainder of the carcass. To test this hypothesis, the proportion of the carcass that was affected by the dark cutting condition was assessed by profiling the yield and quality of 12 different muscles from carcasses with rib eye muscle that had normal colour or were classic (rib eye pH $\geq$ 6.0) or atypical (rib eye pH $\leq$ 5.8) dark cutting LT.

II. MATERIALS AND METHODS

One hundred and seventy nine Canada Grade B4 (dark-cutting) carcass sides were tested for rib eye pH during five different visits to a commercial beef packing plant in Alberta. The muscle pH of one side of each dark cutting carcass was measured at the abattoir using a Fisher Scientific Accumet AP72 pH meter (Fisher Scientific, Mississauga, ON) equipped with an Orion Ingold electrode (Udorf, Switzerland) and fitted a temperature probe to adjust pH for muscle temperature. The pH meter was standardized using pH 4 and 7 standards (Fisher Scientific, Nepean, Canada) and rib eye muscle pH was measured between the 12th and 13th rib site in 3 different locations to ascertain a mean LT pH value for each carcass.

From the carcass sides surveyed, six carcasses were selected at each of the five visits: two classic Canada B4 carcass sides (pH ≥ 6.0), two atypical Canada B4 carcass sides (pH ≤ 5.8), and two Canada AA (normal bright red colour). Selected sides were transported to the Agriculture and Agri-Food Canada Meat Research Laboratory at Lacombe, Alberta, in a refrigerated truck. The carcass sides were weighed upon arrival to determine cooler shrink loss and were chilled overnight until fabrication. At fabrication, the carcass sides were ribbed between the 12th and 13th ribs, were allowed to oxygenate for 20 minutes and were then graded by trained grading personnel. Carcass data collected for each carcass side selected included grade fat, muscle score, cutability estimates, rib eye area (REA), and American Meat Science Association marbling scores (100 – 110; 100 = devoid, 200 = practically devoid, 300 = traces, 400 = slight, 500 = small, 600 = modest). Subjective marbling scores were assigned using the United States Department of Agriculture photographic reference scale (Official USDA Marbling Photographs, National Livestock and Meat Board, Chicago, IL). A transparent muscling grid sheet was used to measure the size of the exposed LT muscle REA. The length and width of the LT muscle was measured using a Canada grade ruler at the 12^{th}-13^{th} rib site to assign yield and muscling scores. Muscle scores ranged from one to four, with one representing the smallest score designating a smaller LT muscle [6]. Following grading, ultimate pH and temperature values were recorded at the rib eye grade site.

The following muscles were dissected from each carcass side: *longissimus thoracis* (LT); *longissimus lumborum* (LL); *psoas major* (PM); adductor (AD); *biceps femoris* (BF); *gluteus medius* (GM); *semimembranosus* (SM); *semitendinosus* (ST); *rectus femoris* (RF); *infraspinatus* (IF); *pectoralis profundus* (PP); and the *triceps brachii* - long head (TB). Muscles dissected from the carcasses had their pH recorded. All muscles except for the rib eye had one 2.5 cm steak removed, which was allowed to oxygenate for twenty minutes at 2 ºC. The colour of this steak was then subjectively assessed by trained personnel using Japan Meat Grading Association colour standards and objectively measured using a Minolta spectrophotometer camera (Minolta CM700D, Minolta Canada, Mississauga, ON).

Significance of the effect of grade on meat quality measurements was determined using the MIXED procedure in the Statistical Analysis Software (SAS) Version 9.2 (SAS Institute Inc., Cary, NC). Frequency data were constructed for colour scores exceeding the AA grade average or those exceeding the JMGA colour score of 7 and a Fishers test was used to determine significance.

III. RESULTS AND DISCUSSION

Survey of 179 Canada grade B4 carcasses led to a re-categorization of dark cutting carcasses based upon rib eye muscle pH. Borderline (BD) dark cutters (5.8 < pH < 6.0) were added as a category in order to define carcasses that had the potential to be dark and tough [7]. Survey results indicated that the majority (72%) of dark cutting carcasses surveyed had LT pH values at the $12^{th}/13^{th}$ thoracic vertebrae greater than 6.0 and were categorized as classic dark cutters (CL). Atypical dark cutting carcasses (AT) with LT pH values of less than 5.8 were present as well, but comprised only about 7% of the population sampled. The remaining carcasses, approximately 21% of the total number of carcasses, had rib eye pH values between 5.8 and 6.0 and were categorized as BD dark cutters.

There was no effect of putative grade category on grade fat, muscle score, fat class or rib eye muscle area; however, CL and BD carcass sides weighed significantly less and had higher mean AMSA marbling scores than Canada AA carcass sides (P< 0.05)(Table 1).

The percentages of the various muscles from each of the putative carcass pH and grade categories that were given a JMGA colour score of greater than or equal to 6.5 are summarized in Table 2. Muscles that are subjectively scored as having a JMGA colour score greater than or equal to 6.5 are considered to be abnormally dark and are penalized [8]. CL carcass sides had the greatest proportion of LT and LL muscles with JMGA colour scores above 6.5, followed by BD and then AT sides. CL carcass sides also had the greatest proportion of AD, GM, SM, ST and PP muscles with JMGA colour scores greater than or equal to 6.5. BD carcasses had a greater frequency of JMGA scores greater than or equal to 6.5 for the AD, BF, GM, SM, ST, IF and TB muscles when compared to AT and AA carcasses. Overall, in CL carcass sides, 10 of the 13 muscles studied had JMGA colour scores greater than or equal to 6.5, while BD, AT and AA carcass sides had 11, 5 and 1 out of 13 muscles, respectively, with JMGA scores greater than or equal to 6.5 (Table 2).

Table 1. Carcass characteristics among putative classes of selected carcasses

Carcass category	n^1	Rib eye pH	Side Weight (kg)	AMSA[2] marbling score
AA[3]	10	NA	204^a	455^b
AT	3	5.74^a	176^{ab}	457^{ab}
BD	7	6.07^a	164^b	511^a
CL	10	6.55^b	169^b	494^a
S.E.M.[4]		0.15	9.13	16.52
P value[5]		0.005	0.004	0.039

[1] Number of carcasses
[2] American Meat Science Marbling Score (100 – devoid; 200 – practically devoid; 300 – traces; 400 – slight; 500 – small; 600 – modest)
[3] AA, Canada AA carcass grade; AT, atypical dark cutting carcass (rib eye pH $\leq$ 5.8); BD, borderline dark cutting carcass (5.8 < rib eye pH < 6.0); CL, classic dark cutting carcass (rib eye pH > 6.0)
[4] Standard error of the mean
[5] Probability (P) of the calculated F value with significance at P $\leq$ 0.05

Muscles from the 'middle' or rib and loin cuts were most affected by the dark cutting condition regardless of pH category, while in the hind quarter, muscle colour varied with pH category. Only the RF and SM muscles were dark for AT carcasses, while all other muscles except for the RF in the CL carcasses were affected in BD and CL carcasses. The *biceps femoris* (BF) and RF muscles were least affected in BD and CL carcasses, and the *semitendinosus* (ST) was quite dark in the CL carcasses while hardly affected in BD carcasses (14%). These results suggested that factors causing glycogen depletion for each dark cutting category potentially differed not only in severity but cause.

Table 2. Proportions (%) of muscles from each carcass category with Japanese Meat Grading Association colour scores greater than 6.5

Muscle	AA[1]	AT	BD	CL
n^2	10	3	7	10
Middle Cuts				
LT[3]	0	67	86	90
LL	0	67	71	100
PM	10	67	29	60
Hind Quarter Cuts				
AD	0	0	43	90
BF	0	0	14	10
GM	0	0	29	70
RF	0	33	14	0
SM	0	33	57	90
ST	0	0	14	90
Fore Quarter Cuts				
IF	0	0	29	20
PP	0	0	0	10
TB	0	0	29	0

[1] AA, Canada AA carcass grade; AT, atypical dark cutting carcass (rib eye pH $\leq$ 5.8); BD, borderline dark cutting carcass (5.8 < rib eye pH < 6.0); CL, classic dark cutting carcass (rib eye pH > 6.0)
[2] Number of muscles
[3] LT, *longissimus thoracis*; LL, *longissimus lumborum*; PM, *psoas major*; AD, *adductor*; BF, *biceps femoris*; GM, *gluteus medius*; RF, *rectus femoris*; SM, *semimembranosus*; ST, *semitendinosus*; IF, *infraspinitus*; PP, *pectoralis profundis*; TB, *triceps brachii*.
[4] Standard error of the mean
[5] Probability (P) of the calculated F value with significance at P $\leq$ 0.05

The muscles within the front quarter were largely unaffected by the dark cutting condition. The IF was dark most often in BD carcasses (29%) and to a reduced extent in CL carcasses (20%). The PP was rarely dark and was only affected in 10% of the muscles from CL carcass sides. The TB was also largely unaffected, except in BD carcasses, and were dark only 29% of the time.

Mean JMGA colour scores for the putative grade categories are listed in Table 3. Even though many muscles were not considered dark (JMGA colour score > 6.5), all muscles except PM, PP and TB darkened as LT pH increased.

Table 3. Mean Japanese Meat Grading Association scores of muscles from each carcass category with colour scores greater than 6.5

Muscle	AA[1]	AT	BD	CL	S.E.M.[2]
n[3]	10	3	7	10	
Middle Cuts					
LT[4]	3.10^{a}	5.08^{b}	6.18^{b}	7.55^{c}	0.39
LL	3.90^{a}	6.67^{b}	7.14^{b}	8.00^{c}	0.28
PM	4.75	4.83	6.14	5.90	0.63
Hind Quarter Cuts					
AD	3.15^{a}	5.33^{b}	5.92^{b}	7.6^{c}	0.51
BF	3.15^{a}	5.90^{a}	4.21^{ab}	5.0^{b}	0.44
GM	2.70^{a}	4.0^{ab}	5.29^{b}	7.0^{c}	0.55
RF	1.85^{a}	4.67^{c}	3.50^{bc}	2.3^{ab}	0.64
SM	3.75^{a}	5.83^{b}	6.50^{b}	7.6^{c}	0.42
ST	1.70^{a}	2.5^{a}	4.0^{b}	7.3^{c}	0.4
Fore Quarter Cuts					
IF	4.35^{a}	4.17^{ab}	5.71^{b}	5.6^{b}	0.44
PP	3.95	4.67	4.86	4.85	0.39
TB	4.2	5.5	5.43	4.65	0.42

[1] AA, Canada AA carcass grade; AT, atypical dark cutting carcass (rib eye pH ≤ 5.8); BD, borderline dark cutting carcass (5.8 < rib eye pH < 6.0); CL, classic dark cutting carcass (rib eye pH > 6.0)
[2] Standard error of the mean
[3] Number of muscles.
[4] LT, *longissimus thoracis*; LL, *longissimus lumborum*; PM, *psoas major*; AD, *adductor*; BF, *biceps femoris*; GM, *gluteus medius*; RF, *rectus femoris*; SM, *semimembranosus*; ST, *semitendinosus*; IF, *infraspinitus*; PP, *pectoralis profundis*; TB, *triceps brachii*.
[a,b,c] Means with different superscripts within a row are significantly different at P < 0.05 according to least square mean differences tests.

IV. CONCLUSION

Results indicated that value may be recovered from the fore quarters of all dark-cutting carcasses and the hind quarters of atypical dark cutting carcasses if these carcasses can be segregated by LT muscle pH.

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REFERENCES

1. Bass, P., Scanga, J., Chapman, P., Smith, G., Tatum, J., & Belk, K. (2008). Recovering value from beef carcasses classified as dark cutters by USDA graders. Journal of Animal Science 86: 1658-1668.
2. Immonen, K., Ruusunen, M., Hissa, K., & Puolanne, E. (2000). Bovine muscle glycogen concentration in relation to finishing diet, slaughter and ultimate pH. Meat Science 55: 25-31.
3. Warriss, P., Brown, S., Adams, S. & Corlett, I. (1994). Relationships between subjective and objective assessments of stress at slaughter and meat quality in pigs. Meat Science 38: 329-340.
4. Tarrant, P., & Sherington, J. (1980). An investigation of ultimate pH in the muscles of commercial beef carcasses. Meat Science 4: 287-297.
5. Wulf, D. M., Emnett, R. S., Leheska, J. M. & Moeller, S. J. (2002). Relationships among glycolytic potential, dark cutting (dark, firm, and dry) beef, and cooked beef palatability. Journal of Animal Science 80: 1895-1903.
6. Jones, S., Jeremiah, L., Tong, A., Robertson, W., & Lutz, S. (1991). The effects of marbling level, electrical stimulation, and postmortem aging on the cooking and palatability properties of beef rib-eye steaks. Canadian Journal of Animal Science 71: 1037-1043.
7. Jeremiah, L., Tong, A. K. W., & Gibson, L. L. (1991). The usefulness of muscle color and pH for segregating beef carcasses into tenderness groups. Meat Science 30: 97-114.
8. Robertson, W. M., Veale, T., Kirbyson, H., Landry, S., and Aalhus, J. L. (2007). Can ultimate pH of the *longissimus* muscle help differentiate borderline dark-cutting beef carcasses from slow-blooming carcasses? Scientific Contributions: Canadian Meat Science Association News.