FINAL REPORT (20 October 2008) Results of practical study.

Identifying practical ways to reduce the prevalence of Dark Cutting Beef (DCB) in young bulls by better animal handling ante-mortem

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Summary

1) Information was collected from 717 bulls which were delivered in 47 consignments from 16 producers to one plant between March and June 2008.

2) The prevalence of DCB assessed in the sirloin was 12.3% based on objective measurements of pH and 8.8% based on subjective assessments. Five per cent of carcasses showed serious dark cutting with a pH greater or equal to 6.0.

3) There was good agreement between objective and subjective assessment methods. Subjective assessment would be an effective way of monitoring DCB on the boning line.

4) The main identified cause of DCB was mixing unfamiliar animals in the pre-slaughter period. As the number of rearing pens from which animals were drafted to make up a consignment increased, so did the amount of fighting and mounting behaviour shown in the lairage, the average pH of the meat, and the %DCB based on both objective and subjective assessments. Producers whose animals exhibited more DCB on average selected the animals in their consignments from a larger number of rearing pens.

5) The overall level of DCB varied slightly, but not significantly, in bulls from different breeds. Dark cutting animals tended to have a slightly lower carcass weight, probably because they grew more slowly. There were no discernible differences in feeding system, transport time, lairage time, or the total time spent from drafting on the farm to slaughter, between animals that produced normal or dark cutting beef. Feed and water provision immediately pre-slaughter was similar for all animals, and variation in ambient temperature was small, and there was no evidence that either of these factors affected the %DCB.

Introduction: Dark Cutting Beef (DCB) is economically of concern to the English meat Industry because consumers discriminate against its abnormal colour, the eating quality is poor, and shelf life may be reduced by its high spoilage potential. Additionally, DCB is often associated with high levels of bruising which can lead to carcass downgrading. Mixing unfamiliar animals before slaughter is considered to be the main factor that leads to DCB, possibly exacerbated by food deprivation and fatigue caused by transport. However, despite our understanding of the principal cause of the problem, the levels of DCB are still apparently commercially important, indicating that cattle are not all being handled optimally ante-mortem. This may reflect gaps in our detailed knowledge of the deleterious effects of specific handling procedures associated with sending animals to slaughter, for example the exact time and duration for which individuals are mixed, or an increased predisposition of some individuals to produce DCB caused by their husbandry during rearing.

The study focused on young bulls produced for a high quality brand of an English multiple retailer. The use of young bulls provided a very sensitive indicator of handling, and particularly mixing, effects, since their relatively aggressive nature predisposes them to engage in agonistic interactions such as butting and mounting. This behaviour results in them being more susceptible to depletion of muscle glycogen, which leads to the elevated ultimate muscle pH (pHu) that causes dark meat. However, the findings will also likely to be applicable to the handling of other classes of cattle (steers, heifers, cull cows).

Aims of the study: The main aims of the study were therefore two-fold:

1) To identify specific husbandry and ante-mortem handling practices used in England that predispose young bulls to produce dark cutting meat.
2) To define a protocol for the optimal handling of young bulls ante-mortem that could form the basis of an Industry “blueprint” to reduce the overall levels of DCB. This aim will be covered in a second report.

Additionally, although not formal aims of the study, it provided the opportunity:

3) To develop and validate a subjective scoring system for the identification of DCB on the boning line.
4) To estimate the prevalence of DCB in young bulls slaughtered at one plant in England.

This report covers Aims 1, 3 and 4. Aim 2 will be addressed in a separate document.

Outline of experimental plan and methodology: The study surveyed the occurrence of DCB in the carcasses of 717 young bulls slaughtered at one plant between March and June 2008. The occurrence of DCB in carcasses was correlated with information relating to the husbandry during rearing, and the ante-mortem handling of the animals derived from detailed records and observations. The animals came from16 producers. Of the total number of bulls sent, meat quality was assessed on between 4 and 156 carcasses from each producer (average 45) over the 14 week study period. Overall, the survey followed 47 deliveries of bulls. Animals were killed on Fridays and each week cattle from two to five producers were represented.

Measurement of meat quality

Carcasses from bulls killed on Friday were de-boned and assessed on the following Tuesday. Measurements and assessments were made on muscles from both sides of the carcass. Normally both sides were available. Right and left sides were not necessarily kept together so were processed independently. Similarly, muscles from the two sides were randomly available from the boning line and were therefore also assessed and measured independently of one another. Carcasses showing DCB were identified at de-boning using two methods (objective and subjective) to assess the quality of the *m. longissimus dorsi* (LD) in the sirloin joint. The LD muscle is known to be particularly prone to glycogen depletion and is therefore a sensitive indicator of DCB in the carcass. Post-mortem changes in pH and colour are known to be completed by 48 hours after slaughter in beef. Assessments were made after the cut surface of the muscle (corresponding to the quartering point) had been exposed to the air for at least 15 minutes to allow the samples to "bloom". In this process the purple de-oxygenated myoglobin pigment at the surface reacts with oxygen in the air and is converted to the bright red oxymyoglobin characteristic of meat under the conditions of normal retail display.

Objective assessment of meat quality

In the objective assessment the colour (CIEL* a* b* system) and ultimate pH (pHu) were measured on the cut surface of the LD at the level of the carcass quartering point (in the region of the insertion of the last rib). Colour was measured in duplicate as the L*, a* and b* coordinates using a Minolta Chroma Meter CR 200. Duplicate measurements of pH were then made using a glass electrode inserted directly into the muscle. The pH meter was calibrated using buffers of pH 5 and 7. The Chroma Meter was calibrated using a standard white plate. Additionally, at the end of the day's readings a standard red plate was read as a control. The a* and b* coordinates were used to calculate Hue and Saturation.

Subjective assessment of meat quality

The muscles were assessed by plant staff independently of the measurements of pH and objective colour. In the subjective method the colour of the LD muscle was assessed using a subjective 3-point category scale (0 = normal colour, 1 = slightly dark, 2 = very dark). This scale was not specifically defined objectively or by reference photographs. However, subsequently we have characterised the scale in terms of objective colour measurements using the CIEL* a* b* system. Practically all the subjective assessments were made by one individual experienced in quality control.

Carcass information

Information on carcass weight and grading was recorded.

Husbandry and handling information

Questionnaires were constructed covering information relating to rearing and husbandry of the animals, handling procedures when the animals were drafted and loaded for transport to slaughter, and handling procedures and conditions in the lairage. Based on interviews with the producer, the questionnaires relating to rearing, husbandry and handling of the animals on the farm, and drafting and loading the animals for transport to slaughter were completed by University of Bristol staff (PDW and SNB) on the initial visit to the farm on the Friday of the first monitored delivery of bulls. This acted as a training opportunity to familiarise the producers with the form of information required. Subsequently, questionnaires for each delivery of animals were completed by the producers themselves and returned to the University of Bristol by post. Information relating to the handling and behaviour of the animals in lairage was collected by SCFF lairage staff.

The husbandry information included details of:

1) estimated animal growth rates
2) nutritional and dietary information
3) numbers of animals per rearing group
4) whether mixing between rearing groups occurred during rearing

The ante-mortem handling information included details of:

1) whether animals were drafted into loading pens prior to loading
2) whether mixing occurred during drafting
3) whether animals from different groups were mixed during drafting, transport and lairage

4) times spent in the drafting, loading, transport and lairage processes
5) provision of food and water during these periods
6) categorisation of ambient temperatures during these periods

Calibration of the subjective assessment system

An additional element of the study was the calibration of the subjective DCB assessment method by defining the relation between the subjective scores (0, 1 or 2) and objective measurements of pHu and muscle colour (L*a*b* values).

Production of a photographic reference scale for the subjective scoring system

We took the opportunity of collecting and photographing examples of LD muscle representing normal, slightly dark and very dark categories. These were transported to the University of Bristol on ice, a fresh surface perpendicular to the long axis of the muscle was cut and this loosely over-wrapped with permeable plastic film to prevent drying. Photographs of the cut surface were taken after allowing the samples to "bloom" in air for at least 15 minutes. Photographs were taken in the afternoon of the day of sample collection. The results of this part of the study will be reported separately.

Recording and analysing data

Meat quality data handling

The objective (instrumental) colour co-ordinates and pH measurements for the two sides were averaged to give one final value for each carcass (so each final value is the mean of 4 readings, 2 from each side). Usually, the subjective assessment scores (0, 1 or 2) for the two sides were the same. In the very rare cases where this was not the case the highest value was recorded for the carcass. In other words, if one side were scored 0 (normal) and the other side 1 (slightly dark), the overall score for the carcass would be 1. Information relating to the live animal was linked to data from its carcass through the animal's ear tag identification (passport number) and the slaughter plant's "kill number" and producer identity.

Data sets

Overall, of the 948 cattle that were delivered for slaughter, we obtained meat quality measurements and assessments on 717 bulls comprising 47 consignments. Missing data occurred because some animals failed to meet the So-Good beef specification, or the carcasses were unavailable for assessment. Information from these animals is comprised of three data sets (Table 1).

Table 1. The information comprising the 3 data sets. A symbol (●,▲,■) indicates that the data is included in the set. The symbol ● indicates that data is available for all 3 data sets. The symbol ▲ indicates data collected directly by University of Bristol staff. The symbol ■ indicates data sent by producers. The number of samples (n) refers to the animals for which we have meat and carcass quality measurements and assessments.

	Rearing & handling on farm	Transport & lairage handling	Carcass & meat quality
Data set 1 (n = 191)	▲	●	●
Data set 2 (n = 247)	■	●	●
Data set 3 (n = 279)		●	●

For 191 of these animals, comprising 11 consignments, (Data set 1) we have complete information on rearing and husbandry from questionnaires we (PDW & SNB) had filled out ourselves on our initial visits to producers at their farms, together with information on handling in lairage and meat and carcass quality measurements and assessments. For a further 247 animals, comprising 17 consignments, (Data set 2) we have the same information except that the questionnaires on rearing and husbandry had been completed by the producers themselves. For a further 279 animals, comprising 19 consignments, (Data set 3) we have no information on rearing and husbandry, or handling, but do have meat and carcass data, and information on handling in the lairage. This was because the animals in this data set were slaughtered at the start of the study period, before we had made our initial visits to the farms, and therefore before we had had a chance to institute the process of questionnaire completion.

Results

Comparison of objective and subjective meat quality assessments

Based on a preliminary inspection of the pH and instrumental colour data it became apparent that three categories of meat could be distinguished based on using limiting pH values of 5.7 and 6.0. These were pH<5.7, corresponding to beef of normal quality, pH $\geq$ 5.7 < 6.0, corresponding to beef which was slightly dark, and pH $\geq$ 6.0, corresponding to beef that was very dark. A pH of 6.0 or above in the LD muscle is generally accepted as indicating the DCB condition. A pH of 5.8 is generally considered to make beef unacceptable for vacuum packing because it can lead to rapid spoilage and colour deterioration. The three quality categories therefore also have a basis in practical experience. The corresponding mean CIEL*a*b* colour coordinates corresponding to meat in each category are given in Table 2. This table also gives the mean colour coordinates corresponding to meat in each subjective category (0, 1 and 2). The similarity between the two sets of coordinates suggests that the three categories based on pH criteria correspond closely to those defined by the subjective scoring system (normal, slightly dark, very dark).

Table 2. CIEL*a*b* coordinates corresponding to the three pH groups in comparison with those corresponding to the three subjective groups. Based on all data (n = 717):

	L*	a*	b*	Hue	Saturation
pH < 5.7	38.0	22.7	12.0	27.9	25.7
score = 0	37.8	22.6	11.9	27.8	25.5
pH ≥ 5.7 < 6.0	34.0	19.2	9.1	25.1	21.2
score = 1	33.6	18.7	8.6	24.6	20.6
pH ≥ 6.0	30.8	16.2	6.8	22.4	17.6
score = 2	30.1	16.3	6.6	22.0	17.6

The L* value is a measure of lightness, higher values indicating a paler colour. The L* value decreases progressively in the two categories corresponding to DCB as the meat appears darker. The a* and b* coordinates measure red-greenness and yellow-blueness respectively. Both also show progressive changes in DCB. These changes are reflected in the Hue and Saturation values. The hue angle decreases indicating a change in colour from an orange-red in normal meat to a purple-red in DCB. Saturation also decreases indicating a less bright/more grey colour. The combination of changes in L*, hue and saturation account for the way humans perceive the difference in colour of normal and dark cutting beef.

The agreement between pH and subjective scoring criteria to identify DCB is shown in Table 3. Overall, if the two categories for DCB are combined, so that beef with a pH ≥

5.7 is considered as dark cutting, and, subjectively, dark cutting is identified by a score of either 1 or 2, then 55 out of 88 (63%) were correctly identified by the subjective score. However, of the 33 carcasses identified as dark cutting by pH criteria but "missed" by subjective assessment, 29 were only slightly dark cutting (with a pH $\geq$ 5.7 < 6.0). Of the carcasses which produced meat that was very dark (pH $\geq$ 6.0), 24 out of 36 (67%) were correctly identified. Only 8 out of 629 normal carcasses (1.3%) were wrongly classed as dark cutting.

Table 3. Agreement between use of pH and subjective scoring to identify DCB

	Subjective score			
	0	1	2	total
normal beef				
pH < 5.7	621	8	0	629
DCB				
pH $\geq$ 5.7 < 6.0	29	15	8	52
pH $\geq$ 6.0	4	8	24	36
Total	654	31	32	717

The overall prevalence of DCB

The information in Table 3 also allows the prevalence of DCB to be calculated. This is given in Table 4. The overall frequency distribution of pH values is shown in Figure 1. Based on pH, 12.3% of carcasses had a pH of $\geq$ 5.7. These were made up of 7.3% that were slightly dark cutting (pH $\geq$ 5.7 < 6) and 5.0% that were very dark (pH $\geq$ 6.0). Based on subjective assessments 8.8% were dark cutting. These were made up of 4.3% that were judged to be slightly dark (given a score of 1) and 4.5% judged to be very dark (given a score of 2). The lower prevalence based on subjective scoring (8.8%) compared with the objective criterion of pH (12.3%) is in accord with general experience that subjective assessments tend to underestimate the prevalence of meat quality problems. Nevertheless, the implication is that, if the current survey reflects the general situation, the overall commercial level of dark cutting in young beef bulls in the UK is probably about 10%.

Figure 1. The Overall frequency distribution of pH values in the sirloin (n = 717). Values of 5.7 and above indicate dark meat.

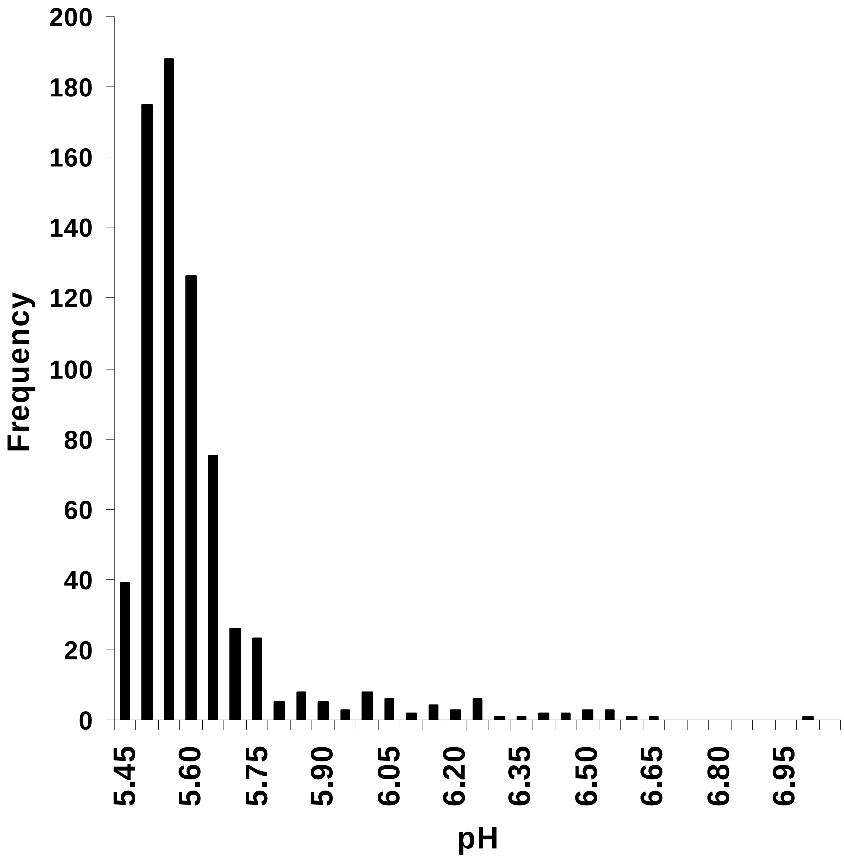

Table 4. The overall prevalence of DCB assessed using pH or subjective scoring.

Prevalence based on pH:

pH < 5.7, n = 629 (mean pH = 5.53)	87.7%	
pH ≥ 5.7 < 6, n = 52 (mean pH = 5.80)	7.3%	
pH ≥ 6.0, n = 36 (mean pH = 6.27)	5.0%	(total number with pH ≥ 5.7 = 12.3%)

Prevalence based on subjective scoring:

Score = 0	n = 654	91.2%	
Score = 1	n = 31	4.3%	
Score = 2	n = 32	4.5%	(total number with score of 1 or 2 = 8.8%)

Factors influencing the prevalence of DCB

The main factor affecting the prevalence of DCB in a consignment of bulls is whether they have undergone mixing with unfamiliar animals in the pre-slaughter period. Normally this would be mixing with other bulls. However, we are aware of one incident in which a consignment of bulls had accidentally escaped from their pen and mixed overnight with a group of steers in an adjacent pen two days before slaughter. Despite being separated the following morning, 9 out of the 24 bulls (38%) produced dark cutting carcasses. It appears therefore that bulls will interact with unfamiliar steers as well as other bulls. Because in this instance the cause of DCB was known specifically, and was not strictly associated with the animals' pre-slaughter handling, we have not included these animals in our analysis below of mixing as a predisposing factor.

It is apparent from the records of handling at loading, during transport and in the lairage that producers are well aware of the need to avoid the mixing of animals. However, mixing may occur when animals are drafted from their rearing pens prior to loading, or in the pens in the transport vehicle, or in the pens in lairage. This is shown in Table 5. Because of the restrictions in the number of available pens, to some degree in the transport vehicle but particularly in lairage, it is almost impossible to keep animals in any but the smallest consignments unmixed. Moreover, because the individual animals are not labelled in any way to indicate that they have come from different rearing pens, even if the number of available pens on the lorry and in lairage were not limiting, it would be impossible for lairage staff to have separated the animals entering the lairage into unmixed groups. Instead, bulls are penned in one or more separate pens based solely on their farm of origin. Animals from different farms are practically never mixed in lairage.

Table 5. The occurrence of mixing during pre-slaughter handling for 27 consignments of bulls (data sets 1 and 2 combined).

	mixing at drafting/loading	mixing in the lorry pens	mixing in the lairage
mixed	6	15	26
<u>not</u> mixed	21	12	1

The figures are cumulative (since animals mixed at one stage must inevitably therefore also be mixed at later stages)

If a consignment consists of only one small group of bulls that have been reared together in the same pen it is likely that they will be un-mixed with unfamiliar animals at the point of slaughter. However, most consignments consist of animals drafted from several rearing pens. In only 25% of consignments did the bulls come from a single rearing pen. In 46% of consignments they came from one or two pens and in 17% of consignments they came from nine or more pens. One consignment was made up of animals from 20 different rearing pens. It also seems likely that the larger the number of animals in a consignment, the more chance that animals will come from more than one rearing pen. In the case of animals coming from more than one pen, mixing is more likely to occur and it is likely that some bulls in the consignment will show dark cutting. We suspect that it is the "dominant" animals in each mixed group that interact most, and therefore are most likely to dark cut, or to produce meat that shows more serious dark cutting in terms of a higher pH value or darker colour. Animals lower in the dominance hierarchy may interact very little or not at all. These may therefore show no greater predisposition to dark cut than if unmixed. However, because we could not record the behaviour of individual animals on the farm, or during pre-slaughter handling, we have no evidence for this.

Logic dictates that it is likely that the prevalence of DCB will be higher in consignments of bulls that are made up of animals drafted from a greater number of rearing pens. The greater the number of pens the greater will be the number of potential interactions between unfamiliar pairs of individual animals. In Table 6 the effect on agonistic behaviour (fighting and mounting) recorded in lairage, and the prevalence of dark cutting, is shown for consignments of bulls made up of animals from different numbers of rearing pens. The behaviour of the bulls in the lairage was recorded subjectively by the lairage staff in terms of the occurrence of the agonistic activities of fighting and mounting. The amount of activity was categorized as low, medium or high. This information was converted into a behaviour index. In this, a score of 1 indicated no fighting or mounting at all; a score of 2 indicated a low level of mounting, or fighting, or both; a score of 3 indicated a medium level of mounting, or fighting, or both; and a score of 4 indicated a high level of mounting, or fighting, or both. As the number of rearing pens comprising the consignment increased the behaviour of the bulls in lairage became more aggressive, the mean pH in the meat increased, and the % DCB increased, whether based on pH measurements or subjective assessment. The correlations between the number of rearing pens comprising the consignment and the percentage of dark cutting carcasses in the consignment were statistically significant for dark cutting assessed using both pH (Spearman's r = 0.404, P = 0.036), and subjective scoring (Spearman's r = 0.403, P = 0.037).

Table 6. The relationship between the number of rearing pens from which a single consignment of bulls came, the animals' behaviour in lairage, and the prevalence of DCB based on pH values or subjective assessment. The analysis is based on the combined information from data sets 1 and 2 and includes a total of 27 consignments.

	Number of rearing pens				
	1	2	3	4	≥ 5
no. of consignments	6	6	4	5	6
no. animals measured	67	124	55	59	109
behaviour index*	1.1	1.4	1.8	2.6	2.5
no. scored $\geq$ 2**	1	1	3	4	5
mean pH***	5.54	5.57	5.59	5.63	5.59
% DCB (pH)	1.5	9.7	14.5	6.8	18.3
% DCB (subjective)	0	3.2	16.4	10.2	10.1

*behaviour index was scored as 1 (none) to 4 (high activity) as described in the text
** number of behavioural scores greater or equal to 2
*** pH was calculated as the average of the mean pH values for each consignment

Feed and water provision immediately pre-slaughter was similar for all animals, with apparently both being available up to the time of loading. Variation in ambient temperature was small and the reliability of some of the data is a little unclear. However, there was no evidence that either of these potential factors affected the %DCB.

Variation between producers in the level of DCB

The number of dark cutting carcasses varied somewhat between producers, as measured by the average pH value of the meat or the % DCB (Table 7).

Table 7. The variation in average pH and % carcasses with pH$\geq$ 5.7 in bulls from different producers. Analysis based on the 717 animals for which we have meat quality measurements.

Producer	number of bulls measured	mean pH	% DCB
1	4	5.47	0
2	10	5.48	0
3	32	5.50	0
4	56	5.53	2
5	44	5.55	9
6	37	5.56	8
7	28	5.56	14
8	56	5.56	13
9	156	5.57	8
10	35	5.59	9
11	20	5.61	20
12	51	5.61	16
13	41	5.63	29
14	73	5.63	19
15	40	5.64	18
16	34	5.73	26

Because of the relatively small sample sizes caution needs to be taken in comparing producers. However, the variation in the level of dark cutting is at least partly a reflection of the way that consignments of bulls were assembled. This is illustrated if the producers for which we have farm data (data sets 1 and 2) are divided into two groups, the first with average pH values ≤ 5.6, the second with average pH values > 5.6 (Table 8).

Table 8. The relationship between % DCB and the average number of rearing pens from which animals were drafted by producers to produce a consignment for slaughter. Analysis based on producers for which we have farm data (data sets 1 and 2).

	Producer group 1 (average pH ≤ 5.6)	Producer group 2 (average pH > 5.6)
number of producers in group	5	6
average number of rearing pens*	2.4	5.6
average % DCB	6.4	17.2

* the average number of rearing pens from which bulls were taken to make up a consignment for slaughter

In the first group the average prevalence of DCB was 6.4%; in the second the average prevalence was 17.2 %. The average number of pens from which the first group assembled their consignments was 2.4 (median value 2) whereas the average number of pens for the second was 5.6 (median value 4). While there is obviously variation between different consignments sent by any particular producer, the implication is that differences in the way animals are penned on the farm, and the strategy followed to market animals to maximise returns, can affect the level of DCB by influencing the potential degree of mixing that takes place. In general, producers who use large pens and follow an all-in, all-out strategy are less likely to need to mix unfamiliar pens of animals when they are sent to slaughter and this lack of mixing will be carried through to handling during transport and in the lairage.

Variation between breeds in the level of DCB

Of the animals for which we have meat quality assessments 75% were British Friesian (n = 175) or Holstein Friesian (n = 344), the remaining animals coming from various other breeds and breed crosses. The Holstein Friesians had a slightly higher pH overall and a slightly higher prevalence of dark cutting carcasses than the British Friesians (Table 9). However, these breed differences were not significant.

Table 9. Measures of DCB in British Friesian (BF), Holstein Friesian (HF) and "other" breed bulls

	British Friesian	Holstein Friesian	Other
Number of animals measured	175	344	169
Average pH	5.57	5.59	5.57
% DCB based on pH	9.1%	13.4%	10.1%
% DCB assessed subjectively	7.4%	9.3%	5.3%

No differences between breeds were statistically significant.

Other factors measured which could have potentially influenced the % DCB

The average values for carcass weight and fatness, growth and times spent in pre-slaughter handling are shown in Table 10. Dark cutting animals had very slightly, but significantly ($t = 2.6$, $P < 0.01$) lighter carcasses (270 $\pm$ 21(standard deviation) vs 275 $\pm$ 17(standard deviation) kg) than animals producing normal beef despite being the same age at slaughter. They therefore had a slightly lower growth rate, although this was not significant ($t = 1.3$, ns). This could be explained by the fact that some producers may "discard" poorly-growing animals by sending them to slaughter early. These individual animals may stand a greater chance of being included with other pens of animals, and therefore mixing with unfamiliar bulls. They therefore also have a greater chance of producing dark cutting carcasses. Carcass fatness between dark cutting and normal groups was similar.

Mean pre-slaughter handling times in transport, lairage and in total were the same in dark cutting and normal groups. Transport time ranged from 60 to 360 minutes, lairage time from 0 to 1020 minutes and total time from 60 to 1080 minutes. A lairage time of 0 implies what is often referred to as "tailboard slaughter" where the animals are killed immediately on arrival at the slaughter plant. One consignment was so treated. In this consignment 3 out of 26 bulls (11.5%) showed DCB (with an average pH of 5.96). This suggests that the use of tailboard slaughter will not invariably prevent DCB although it may be beneficial in some situations. It is possible that the lack of a discernible effect on DCB of variation in pre-slaughter handling times could reflect the small sample size combined with the large effect of mixing unfamiliar animals. It is conceivable that a very extensive survey might have shown such effects. The lack of an effect of lairage time implies that only a very short mixing time may be necessary to produce DCB.

As discussed previously, the number of rearing pens from which slaughter consignments were assembled was higher in the dark cutting group (7.0 *vs* 3.7) but the number of pens in which they were held in lairage was similar (1.8 *vs* 1.7).

Table 10. Average values for carcass weight and fatness, growth and pre-slaughter handling parameters for animals that produced normal beef and those that produced DCB.

	Normal	DCB
Carcass weight (kg)	275	270 **
Fat score	2.48	2.49 ns
Age at slaughter	426	426 ns
Growth rate (kg/day)	0.65	0.64 ns
Transport time (minutes)	159	162 ns
Lairage time (minutes)	150	158 ns
Total time (minutes) º	309	319 ns
No. of pens bulls came from on farm	3.7	7.0
No. of pens used when held in lairage	1.7	1.8

** Difference between carcass weights is significant ($t = 2.6$, $P < 0.01$).
Non-significant differences between means are indicated by ns ($P > 0.05$).
º Total time includes time spent in loading, transport and lairage.

Conclusions

The prevalence of DCB assessed in the sirloin was 12.3% based on objective measurements of pH and 8.8% based on subjective assessments. Five per cent of carcasses showed serious dark cutting with a pH greater or equal to 6.0.

There was good agreement between objective and subjective assessment methods. Subjective assessment would be an effective way of monitoring DCB on the boning line.

The main identified cause of DCB was mixing unfamiliar animals in the pre-slaughter period. As the number of rearing pens from which animals were drafted to make up a consignment increased, so did the amount of fighting and mounting behaviour shown in the lairage, the average pH of the meat, and the %DCB based on both objective and subjective assessments. Producers whose animals exhibited more DCB on average selected the animals in their consignments from a larger number of rearing pens.

The overall level of DCB varied slightly, but not significantly, in bulls from different breeds. Dark cutting animals tended to have a very slightly lower carcass weight, probably because they grew more slowly. There were no discernible effects on DCB of feeding system, transport time, lairage time, or total time spent from drafting to slaughter. Feed and water provision immediately pre-slaughter was similar for all animals, and variation in ambient temperature was small, and there was no evidence that either of these factors affected the %DCB.

Some caution needs to be exercised in interpreting the results because the size of the data set is relatively small and because there is considerable confounding between factors.

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