End of Project Report

VARIATION IN THE QUALITY OF MEAT FROM IRISH STEERS AT THE TIME OF SLAUGHTER

Authors

A.P. Moloney[1,2], A.M. Mullen[2], S.C. Maher[1,2],
D. J. Buckley[3] and J. P. Kerry[3]

[1] Teagasc, Grange Research Centre, Dunsany, Co. Meath
[2] Teagasc, The National Food Centre, Ashtown, Dublin 15
[3] Department of Food and Nutritional Sciences, University College, Cork

Beef Production Series No. 59

GRANGE RESEARCH CENTRE
Dunsany
Co. Meath
ISBN 1 84170 361 1

2004

Teagasc — Agriculture and Food Development Authority

The National Food Centre

Contents

1. Summary/Conclusion

There is no information on the variation in quality, in particular tenderness, that exists in Irish Beef nor is there information on the variation that would remain if optimum practices were imposed at all stages of the beef production chain. Evaluation of the success of measures to improve beef consistency requires information on existing variation and the minimum variation achievable. The objectives of this project were (i) to establish the variation that exists in the quality of meat from Irish cattle, (ii) to quantify the minimum variation in meat quality that can be achieved in a practical beef production system, (iii) to determine the effects and mechanisms of additional sources of variation.

The conclusions from this project are:

- The *M. longissimus dorsi* (loin) was found to be more variable than the *M. semimembranosus* (topside) for most quality attributes examined (tenderness, sarcomere length and pH). The scale of variation within the loin was similar to that reported by the other research groups within the EU and US. Heifers were more variable than steers for most attributes, while there was no consistent classification effect on the variability of meat quality attributes.
- Tenderness was equally variable in meat from genetically similar steers, managed similarly, compared to commercial steers randomly selected from a factory lairage but matched for weight and grade. This was likely a result of both groups being crossbred beef cattle of similar age, fat score, carcass weight and managed identically post-mortem. However, variation in tenderness of both groups was less than that observed in a survey of commercial throughput (experiment 1). This decrease is attributed to better pre-and-post-slaughter handling practices.
- The data suggest that selection of sires (within a breed) with better than average conformation has no deleterious effect

on the eating quality of beef of their progeny. A more comprehensive comparison of sires within a breed and between breeds is required to confirm the generality of this conclusion.

- In a comparison of genotypes, gender and slaughter weights, there was no evidence that variation around the mean value for tenderness differed between breeds or liveweights after 14 days ageing. Bulls were more variable than steers for some quality traits but the variation in tenderness was similar for bulls and steers after 14 days ageing.
- While optimising the management of animals during the pre and post-slaughter period reduced variation in tenderness, some residual variation remained. A large percentage of the residual variation in tenderness (Warner Bratzler shear force) after 2 and 7 days post-mortem was explained by proteolysis (breakdown of myofibrillar proteins). Variation in tenderness (Warner Bratzler shear force) after 2 days post-mortem was largely explained by phosphates (energy) and proteolysis, while sensory tenderness was largely explained by phosphates and glycolytic potential.
- Further work is required to reduce residual variation in Irish beef and to determine the causes of this variation.

2. Introduction

The perception of inconsistency of meat quality, in particular tenderness, is harmful to efforts to market Irish beef. There is no information on the variation in quality that exists, nor is there information on the variation that would remain if optimum practices were imposed at all stages of the beef production chain. Evaluation of the success of measures to improve beef consistency requires information on existing variation and the minimum variation achievable. The objectives of this project were (i) to establish the variation that exists in the quality of meat from Irish cattle, (ii) to quantify the minimum variation in meat quality that can be achieved in a practical beef production system, (iii) to determine the effects and mechanisms of additional sources of variation.

In this collaborative study between Grange Research Centre and The National Food Centre, the scale of variation in meat quality attributes of Irish beef was quantified and additional sources of variation identified. This information will provide a target on which to focus efforts to improve consistency of Irish beef. Information on the increase in consistency of individual meat quality attributes that can be achieved by manipulation of "on-farm" factors will assist in the development of quality beef production systems.

3. General Methods

Cattle were captive bolt stunned and exsanguinated conventionally at the research abattoir or at a commercial beef processing plant. Excised muscle (*M longissimus dorsi*-loin) and *semimembranosus* – topside) as appropriate, was aged at 0°C to +2°C up to 14 days post-slaughter.

Steaks 2.5 cm thick, were cut after 2, 7 and 14 days ageing for Warner-Bratzler shear force (WBSF) measurements. Steaks were cut after 14 days for colour measurements, wrapped in an oxygen permeable PVC wrap and allowed to bloom at 4°C for 3h.

Cattle were produced, as required, at Grange Research Centre. Meat colour and eating quality were measured at The National Food Centre. The lightness 'L', redness 'a' and yellowness 'b' colour coordinates of lean meat were measured using a HunterLab Ultrascan XE colorimeter.

Tenderness was assessed instrumentally and organoleptically using standard protocols. Shear force, an instrumental measure of tenderness, was measured using an Instron Model No. 1140 with a Warner Bratzler blade attachment. Sensory analysis was carried out using the protocols of the American Meat Science Association (AMSA, 1978). Steaks were grilled to an internal temperature of 70°C and judged by trained taste panellists. Panellists were asked to assess the samples on a hedonic scale of 1-8 as follows:

Tenderness	scale 1-8	1 = extremely tough	8 = extremely tender
Juiciness	scale 1-8	1 = extremely dry	8 = extremely juice
Flavour	scale 1-5	1 = very poor	5 = very good
Firmness	scale 1-8	1 = extremely mushy	6 = extremely firm
Texture	scale 1-6	1= very poor	6 = extremely good
Overall acceptability	scale 1-6	1 = not acceptable	6 = extremely acceptable

Since the project was primarily concerned with the variation around means for particular attributes, the variance which is the square of the standard deviation, (a measure of the spread around a mean) is shown in the Tables. The coefficient of variation

($CV = 100\frac{SD}{Mean}$) is also presented. The use of CV allows a comparison of the variation around a mean which is independent of the units of measurement. The mean value is also given for reference.

Experiment 1: Variation in the eating quality of meat from Irish steers and heifers

Introduction

Variation in the eating quality of beef is one of the primary concerns of the meat industry. Evaluation of the success of measures to improve the consistency of beef quality requires knowledge of the existing variation. The objective was to quantify the scale of variation in the eating quality in particular tenderness, of beef striploin and inside round (topside). Muscles were excised from steers (n=81) and heifers (n=77), of EUROP carcass classification O4H, O4L, R4H, R4L, at 1d or 2d post-mortem in two commercial meat plants and stored at 4°C. Samples (2.5 cm thick) were taken for quality assessment at 14 days post-mortem. pH, electrical impedance, colour, sensory attributes, Warner Bratzler shear force (WBSF) and sarcomere length were recorded for all samples. Variances within all 8 EUROP classification and gender combinations were compared using Bartlett's procedure.

Results:

Shear force

The variances across the 8 carcass classification/gender combinations for WBSF of the loin was not homogenous ($p<0.001$) (Table 1). This lack of homogeneity resulted from O4H steers having a lower ($P<0.05$) variance value than other classifications. There was no significant difference in variances between classification grades within heifers.

The variances across 8 carcass classification/gender combinations of WBSF of the topside was not homogenous ($P<0.05$) (Table 1). This lack of homogeneity was a result of steers having lower variances ($P<0.01$) compared to heifers. There was no significant difference in variances between classification grades for the topside muscle. The coefficient of variation for the loin was greater than observed within the topside (Table 1).

Within the loin, 64% of samples analysed were tender (<50N), with only 38% of the SM muscles measured being tender (<50N). For both the loin and topside, a greater percentage of steers (75% and 48%, respectively) were tender (50N) compared to heifers (52% and 27%, respectively). More 'R' grade samples (67%) were tender (<50N) compared to 'O' grade (61%) for the loin. There was little difference in percentage of tender (<50N) 'R' grade samples (39%) compared to 'O' grade (37%) for the topside. There was little difference in percentage of tender (<50N) '4H' fat class samples compared to '4L' fat class within the loin (61% and 66%, respectively) and the topside (36% and 39%, respectively).

Sensory attributes

Variances for the 8 carcass classification/gender combinations were homogenous for most sensory attributes when both the loin and topside were tested by a sensory panel. Variances for overall acceptability of the loin differed ($P<0.05$) between the 8 carcass classification/gender combinations. This was a result of R4H steers having a larger variance ($P<0.05$) compared to other grades. There was no significant difference in variances between classification grades within heifers (Table 1). In general, loin had larger variances compared with the topside for sensory attributes. For both the LD and SM muscles, heifers had a higher variances compared to steers within most sensory attributes.

Conclusion

The loin was more variable than the topside for most quality attributes examined. The scale of variation within the loin was similar, or greater, than that reported by other research groups within the EU and US. The topside was more variable than the loin for Hunter L, a, b, colour and chemical composition. Heifers were more variable than steers for most attributes, while there was no consistent classification effect on the variability of meat quality attributes.

Table 1: **Variance, (mean) and coefficient of variation (CV) of Warner Bratzler shear force (WB; newtons) and sensory attributes of the *M. longissimus dorsi* (loin) and the *M. semimembranosus* (topside) aged for 14 days for post-mortem.**

		STEERS				HEIFERS				CV	Sig
		O4H	O4L	R4H	R4L	O4H	O4L	R4	R4L	%	p
		n=20	n=23	n=20	n=18	n=23	n=21	n=19	n=14		
WB	Loin	68.5	232.3	204.3	199.9	403.9	335.9	410.0	531.9	35.8	***
		(41.7)	(46.4)	(43.9)	(45.8)	(56.9)	(48.9)	(51.8)	(52.8)		
	Topside	30.8	73.0	72.0	81.9	118.4	95.5	164.3	107.9	18.7	*
		(48.6)	(52.2)	(53.8)	(53.0)	(58.8)	(57.0)	(58.1)	(49.9)		
Td[1]	Loin	0.6	0.6	0.9	0.3	1.0	1.4	0.9	1.2	18.5	ns
		(5.8)	(5.7)	(5.5)	(5.2)	(4.8)	(5.0)	(5.1)	(5.3)		
	Topside	0.6	1.0	0.7	0.3	0.9	0.7	0.4	0.6	16.6	ns
		(4.9)	(5.3)	(4.7)	(4.7)	(4.9)	(4.9)	(4.9)	(4.8)		
Fv[2]	Loin	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	9.8	ns
		(4.0)	(4.0)	(3.8)	(3.6)	(3.8)	(3.9)	(3.7)	(3.7)		
	Topside	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	8.5	ns
		(3.8)	(3.7)	(3.6)	(3.7)	(3.8)	(3.9)	(3.8)	(3.6)		
Fm[3]	Loin	0.3	0.3	0.4	0.4	0.3	0.4	0.4	0.5	11.9	ns
		(4.9)	(5.0)	(5.1)	(5.1)	(5.5)	(5.4)	(5.3)	(5.4)		
	Topside	0.2	0.3	0.2	0.2	0.3	0.3	0.2	0.2	9.1	ns
		(5.5)	(5.5)	(5.5)	(5.5)	(5.8)	(5.9)	(5.7)	(6.0)		
Tx[4]	Loin	0.3	0.2	0.5	0.2	0.6	0.6	0.5	0.4	20.8	ns
		(2.8)	(3.0)	(3.1)	(3.2)	(3.5)	(3.4)	(3.5)	(3.3)		
	Topside	0.2	0.3	0.3	0.2	0.4	0.2	0.3	0.2	14.3	ns
		(3.5)	(3.4)	(3.5)	(3.5)	(3.7)	(3.8)	(3.5)	(3.8)		
OA[5]	Loin	0.1	0.2	0.3	0.1	0.4	0.4	0.2	0.2	15.2	*
		(3.9)	(3.8)	(3.7)	(3.5)	(3.4)	(3.6)	(3.3)	(3.3)		
	Topside	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	12.3	ns
		(3.6)	(3.5)	(3.5)	(3.4)	(3.4)	(3.4)	(3.6)	(3.3)		

[1]Tenderness: , [2]Overall flavour: [3]Overall firmness: , [4]Overall texture: , [5]Overall Acceptability.
p-value of differences between variances (*p=0.05, ***=0.001, ns = non-significant).

Experiment 2: Decreasing the variation in tenderness of beef through homogenous pre- and post-slaughter management

Introduction:

In experiment 1, the CV for WBSF of 14 day-aged beef was 36% for loin and 19% for topside. The CV% for sensory tenderness was 18% for loin and 16% for SM. Therefore, the objective of this experiment was to determine the effectiveness, under Irish conditions, of current "best-practice" management of steers pre- and post-slaughter in reducing variation in the eating quality of beef compared to a commercial herd and the results of experiment 1.

A pool of steers, sired by one Belgian Blue bull, from Holstein-Friesian cows was managed from birth to slaughter according to a blueprint for 2 year old dairy beef production (Keane and O'Riordan, 1998). These were considered homogenous (H). Animals were slaughtered at target body weights of 620kg (n=23) (LH – light homogenous) or 720kg (n=24) (HH – heavy homogenous). On each occasion H animals were slaughtered, steers with similar carcass weights and classification scores to H were selected from the factory lairage (n=19 for light lairage steers (LC) and n=20 for heavy lairage steers (HC)). All animals were managed similarly through slaughter and post-mortem chilling. Carcasses were aitch-bone hung in the same chill for 24hr prior to excision of LD and SM muscles. Following ageing for a total of 14 days post-mortem, tenderness was assessed as WBSF and by an 8 member trained sensory panel. Homogeneity of variance among the 4 groups of animals was tested using Bartlett's test.

Results:

Carcass weights for light and heavy homogenous steers (LH and HH) were 332kg ±10.0 and 401kg ±12.63, respectively. The carcass weights for light and heavy lairage steers (LC and HC) was 346.5kg±32.3 and 383.7kg±21.32, respectively. The variances between groups for WBSF of the loin were different ($P<0.05$) at 7 days post-mortem, but not at days 2 and 14 post-mortem (Table 3).

The differences after 7 days ageing were due to HC having lower variance compared to HH (P<0.05) and LC (P<0.01). No difference was observed between variances when commercial groups (LC and LH) or homogenous groups (HH and LH) were compared.

The variance was not different between the groups for WBSF of the topside muscle at days 2 and 7 post-mortem. There was a difference (P<0.05) after 14 days ageing (Table 3), due to HC having greater (P<0.05) variances compared to LC. No difference was observed between the variances of HH and LH, HH and HC or LH and LC.

For both the loin and topside, a greater percentage of homogenous steers (95.7% and 82.9%, respectively) were tender (<50N) compared to commercial steers (84.6% and 66.7%, respectively) after 2 days ageing.

For the majority of sensory attributes, the variances within either muscle were not statistically different between the groups. The exception to this was texture of the topside, which differed (P<0.05) due to HH having greater variances compared to LH, LC and HC. No difference was observed for the variances of LC and LH or HC and LC.

After 14 days ageing, 100% of loins and 71% of the topsides from both homogenous and commercial samples were considered greater than slightly tender ($\geq$5). A larger percentage topside from homogenous steers (94%) were greater than slightly tender ($\geq$5) compared to commercial steers (56%) after 14 days ageing.

For LH and HH animals, CV for WBSF was 13% for loin and 16% for topside. Corresponding CV for sensory tenderness was 9% and 13 %, respectively. For LC and HC animals, CV for WBSF was 12% for loin and 19% for topside. Corresponding CV for sensory tenderness was 8% and 9%, respectively.

Within the loin muscle, variances reported in experiment 1 for individual and pooled light and heavy steers were significantly greater for WBSF compared to the individual and pooled light and heavy steers of both the homogenous and commercial steers in the present study.

Within the topside muscle, variances reported in experiment 1 for individual and pooled steers of light and heavy steers were significantly greater for most quality attributes compared to the individual and pooled light and heavy steers of both the homogenous and commercial steers.Variances reported in experiment 1 for both light and heavy steers combined were significantly greater for sensory tenderness and WBSF compared to LH and HH combined or LC and HC combined.

Table 2. Variance, (mean) and coefficent of variation (CV) of Warner Bratzler shear force (WB; newtons) of *M. longissimus dorsi* (loin) and *M. semimembranosus* (topside) from light homogenous (LH), light commercial (LC), heavy homogenous (HH), and heavy commercial (HC) steers.

WB	Muscle	LH (n=23)	LC (n=19)	HH (n=24)	HC (n=20)	Sig	CV%
2d	loin	29.9 (41.8)	33.4 (45.1)	38.5 (37.8)	58.0 (45.2)	ns	16.4
7d	loin	25.9 (39.3)	46.3 (40.2)	29.8 (41.2)	11.6 (40.1)	*	13.1
14d	loin	35.3 (38.6)	16.5 (38.0)	16.6 (37.1)	19.9 (42.9)	ns	13.2
2d	Topside	39.1 (47.2)	40.5 (46.8)	26.2 (39.7)	74.6 (47.1)	ns	16.2
7d	Topside	42.8 (48.9)	27.7 (53.6)	50.0 (47.5)	45.9 (51.4)	ns	13.4
14d	Topside	43.5 (47.7)	49.2 (50.8)	82.4 (52.9)	148.9 (56.2)	*	18.0

p-value* of differences between variances *(*=<0.05,* ns = non-significant*).

Conclusion:

Tenderness was equally variable in meat from genetically similar steers (HS) compared to randomly selected lairage steers (LS), which was likely a result of both groups being crossbred beef cattle of similar age, fat score, carcass weight and managed identically post-mortem. However, variation in tenderness of both groups was less than that observed in a survey of commercial throughput (experiment 1).This decrease is attributed to optimal pre- and post-slaughter handling practices.

Experiment 3: Tenderness and eating quality of beef from the progeny of two charolais sires

Introduction:

Much research has been carried out on the influence of breed on the composition and eating quality of beef. Relatively less information is available about the differences in meat quality due to sires within a breed. Beef carcasses with 'good' conformation achieve higher prices in EU markets but little is known about the consequences of sire selection on the variability of meat quality traits. The objective of this study was to compare the composition and eating quality of meat from the progeny of a Charolais sire of 'average' conformation (muscularity) with that of a Charolais sire of 'good' conformation. Two sires, of no genetic relationship, were chosen. The sire of average conformation (CF44) had an expected progeny difference (EPD) for growth, conformation and fatness of 56.7, 0.99 and –0.02, respectively. The sire of good conformation (IC27) had good EPD for growth, conformation and fatness of 51.9, 1.23 and –0.13, respectively. Both sires were crossed with Limousin X Friesian or Simmental X (Limousin X Friesian) cows. Young bull progeny of CF44 (n=14) and IC27 (n=16) were spring born, single suckled and weaned October 17, 2000. All animals received a grass silage and concentrate diet until slaughter on June 5, 2001 when 450 days of age. The young bulls were slaughtered together and the carcasses hung conventionally for 24 h post-mortem. This was then excised and aged for 2, 7 and 14 days post-mortem. Mechanical tenderness (WBSF), colour (Hunter Lab), pH, electrical conductivity, sarcomere length, chemical composition and drip loss were measured. Variances for each sire were compared using Bartlett's procedure.

Results:

There was no significant difference between liveweights of the progenies of the two sires, with average liveweight at slaughter of 647.4 kg for progeny of CF44 and 626.8 kg for progeny of IC27. There was no difference between the carcass weights of progeny from sires with 'good' conformation (375kg) and those with 'average' conformation

(378kg). There was no difference in the variation in tenderness and eating quality of the beef from progeny of the 'average' or the 'good' conformation sires (Table 4).

Conclusion:

Differences between sires in EPD for musculature were reflected in the musculature of their progeny. The data suggest that selection of sires (within a breed) with better than average conformation has no deleterious effect on the eating quality of beef of their progeny. However, a more extensive comparison of sires within a breed and between breeds is required. The results of this experiment and the data from experiments 1 and 2 also suggest that pre-slaughter environmental factors and post-slaughter handling of carcass make a much larger contribution to variation in tenderness than genetic selection within a breed.

Table 3. Warner Bratzler shear force (WB; newtons) after 2, 7 and 14 days ageing and sensory attributes after 14 days ageing of loins from progeny of Charolais sires of average (CF44) and good (IC27) conformation.

	CF44 (n=14)	±SD	IC27 (n=16)	±SD	Sig	CV%
WB 2d postmortem	80.9	17.5	84.6	17.1	ns	20.6
WB 7d postmortem	65.6	13.4	63.4	12.8	ns	20.0
WB 14d postmortem	57.6	13.3	59.2	15.7	ns	24.6
Tenderness	5.3	0.8	5.3	0.8	ns	15.0
Juicness	5.5	0.8	5.3	0.7	ns	13.0
Flavour	4.3	0.2	4.3	0.2	ns	5.5
Firmness	5.3	0.6	5.4	0.4	ns	9.1
Texture	3.3	0.6	3.4	0.5	ns	16.5
Overall acceptability	3.8	0.6	3.9	0.5	ns	13.5

Mean values (ns = non-significant).

Experiment 4: Tenderness and eating quality of beef from a dairy and beef-cross dairy breed

Introduction:

It has been suggested that selection for increased milk yield from dairy cows may negatively impact on the eating quality of beef from their male offspring. The aim of this experiment was to determine the extent of variation in the eating quality of beef from light or heavy steers and young bulls from extreme dairy or beef cross dairy breeds of cattle. High genetic merit New Zealand Holstein-Friesian dairy progeny (NZ), high genetic merit European/North American Holstein-Friesian dairy progeny (EU) and Belgian Blue beef cross Holstein-Friesian progeny (BB) (32 per genotype) were reared from birth to slaughter as light (620kg) steers, heavy (720kg) steers, light young bulls or heavy young bulls. Within genotype, animals were blocked according to gender; steer (n = 16) or young bull (n = 16) production. The management of all animals was outlined in detail by Keane (2003). The bulls had an average age of 18-19 months and steers 25 months. Within genotype the average age was 21 months. The cube roll (loin) was excised 24 h post mortem and stored at 4°C for 48 h post-mortem. Tenderness, WBSF, sarcomere length, pH, electrical conductivity, cook loss, and composition measurements were made at 2, 7 and 14 days post-mortem. The variances within the 12 gender, liveweight and genotype combinations were compared using Bartlett's procedure. Variances for the three genotypes, the two genders and two liveweights were also compared separetely using Bartlett's procedure.

Results:

Variances were not homogenous ($P<0.05$) for WBSF after 2, 7 or 14 days ageing for the 12 gender, liveweight and genotype combinations. Within gender, the variance for WBSF after 2 days ageing was greater ($P<0.001$) for bulls than steers (558.9 v 149.1). There was no difference in variance between the two liveweights (heavy = 260.02 and light = 456.09) or the three genotypes (NZ = 404.85, EU = 405.41 and BB = 269.94). Within gender, the variance for WBSF after 7 days ageing was greater (P<0.01) for bulls than steers (267.2 v 93.4). There was no significant difference in variance between the two liveweights (heavy = 138.57 and light = 213.71) or the three genotypes (NZ = 152.48, EU = 220.74 and BB = 180.02). The variance for WBSF after 14 days ageing was similar within gender (bulls = 151.6 and steers = 84.9), liveweight (heavy = 120.3 and light = 116.1) and genotype (NZ = 125.2, EU = 147.9 and BB = 82.9). However, EU light bulls appeared to be more variable compared to all the other combinations of gender, liveweight and genotype.

After 2 days ageing 59% of NZ, 41% of EU and 66% of BB samples were tender (WBSF<50 Newtons). Within gender, 46% of bull and 66% of steer samples were tender. Within liveweight, 60% of heavy and 50% of light samples were tender. After 7 days ageing 66% of NZ, 59% of EU and 75% of BB samples were tender. Within gender, 54% of bull and 79% of steer samples were tender. Within liveweight, 73% of heavy and 60% of light samples were tender. After 14 days postmortem 84% of NZ, 81% of EU and 91% of BB samples were tender. Within gender, 81% of bull and 90% of steer samples were tender. Within liveweight, 83% of heavy and 88% of light samples were tender.

Sensory analysis

Variances were homogenous for the 12 gender, liveweight and genotype combinations for all sensory attributes measured except flavour (P<0.001). Within gender, the variance for flavour was greater (P<0.05) for bulls than steers (0.21 v 0.10). There was no significant difference in variance between the two liveweights (heavy = 0.19 and light = 0.16) or the three genotypes (NZ = 0.11, EU = 0.22 and BB = 0.19).

After 14 days ageing 91% of NZ, 81% of EU and 94% of BB samples were tender (≥5 on the sensory tenderness scale). Within gender, 88% of bull samples and 89% of steer samples were tender. Within liveweight, 83% of heavy and 94% of light were tender.

Table 4. Variances, (means) and coefficient of variation (CV) for Warner Bratzler shear force (WB; newtons) and sensory attributes of loins from steer and bull progeny of light (620kg) and heavy (720kg) live weight from New Zealand dairy (NZ), European/North American dairy (EU) and Holstein-Friesian dairy cross Belgian Blue beef (BB) breeds.

Gender	STEERS						BULLS						CV	Sig.
Weight	LIGHT			HEAVY			LIGHT			HEAVY			%	P
Breed	NZ (n=8)	EU (n=8)	BB (n=8)	NZ (n=8)	EU (n=8)	BB (n=8)	NZ (n=8)	EU (n=8)	BB (n=8)	NZ (n=8)	EU (n=8)	BB (n=8)		
WB (2d)	192.47 (45.18)	74.39 (53.92)	100.29 (49.69)	111.94 (40.28)	303.14 (52.67)	74.33 (48.42)	864.30 (58.45)	924.60 (67.55)	568.76 (55.17)	335.78 (58.01)	314.24 (52.84)	357.63 (42.38)	36.66	**
WB (7d)	60.43 (37.13)	131.61 (45.51)	28.13 (43.39)	67.34 (37.57)	132.93 (48.99)	86.22 (42.47)	159.21 (50.35)	397.56 (54.31)	344.00 (57.16)	252.51 (44.51)	166.97 (38.61)	111.56 (38.47)	30.23	*
WB (14d)	136.99 (38.06)	35.21 (36.26)	30.61 (42.45)	104.97 (32.66)	62.98 (39.67)	96.34 (44.38)	37.26 (35.22)	364.83 (45.48)	67.83 (34.88)	183.05 (44.69)	125.71 (36.10)	104.66 (37.12)	27.79	*
Tenderness	0.81 (5)[1]	0.79 (5)	0.13 (6)	0.50 (6)	0.27 (5)	0.79 (6)	1.14 (6)	1.14 (6)	0.84 (6)	0.55 (5)	0.55 (6)	0.79 (6)	13.55	ns
Flavour	0.24 (4)[1]	0.27 (4)	0.29 (4)	0.27 (4)	0.41 (4)	0.13 (4)	0.13 (4)	0.57 (4)	0.21 (4)	0.00 (4)	0.50 (4)	0.21 (4)	10.21	***
Firmness	0.14 (5)[1]	0.27 (6)	0.29 (5)	0.29 (5)	0.27 (6)	0.21 (6)	0.29 (5)	0.29 (5)	0.50 (5)	0.50 (6)	0.27 (5)	0.21 (5)	9.32	ns
Texture	0.48 (3)[1]	0.50 (3)	0.57 (3)	0.13 (3)	0.41 (3)	0.41 (3)	1.13 (3)	0.55 (3)	0.70 (3)	0.50 (3)	0.21 (4)	0.50 (3)	19.53	ns
Acceptability	0.29 (4)[1]	0.41 (4)	0.21 (4)	0.21 (4)	0.41 (4)	0.21 (4)	0.21 (4)	0.29 (4)	0.50 (4)	0.13 (4)	0.21 (4)	0.21 (4)	12.39	ns

[1]n = 7

Conclusion:

Bull beef was more variable than steer beef for several of the quality characteristics examined. However, after ageing for 14 days post-mortem, variation around average values for eating quality characterises was similar when the 3 breeds, 2 genders or 2 pre-slaughter liveweights were separately compared. This indicates that modifications of these factors within a beef production system will not add to variation in the eating quality of 14 day-aged beef.

Experiment 5: Residual variation in tenderness after identical management of cattle, pre- and post-slaughter, and its biochemical explanation

Introduction:

After ageing for 14 days, the CV for WBSF for loins from genetically similar steers, managed optimally pre- and post-mortem was 13%. The CV for sensory tenderness of loin was 9% (Experiment 2). We hypothesed that this remaining variation reflected variable rates of proteolysis, glycolysis and /or collagen content.

Animals were selected from the same pool of animals used in experiment 2 with similar “best-practise” pre- and post-mortem management applied. Steers (*n*=10) achieved an average liveweight of 661kg, an average daily gain (ADG) of 0.7kg/day and were, on average, 28 months of age at slaughter. Animals were handled pre-slaughter and post-slaughter with the aim of minimising stress. Persons familiar to the cattle carried out all handling. Transport to the abattoir (Meat Industrial Development Unit, Teagasc, National Food Centre, Dublin) was on the morning of slaughter and the journey lasted approximately 1 hour. Cattle were held for approximately 1 hour in the lairage in the same groups in which they were finished on the farm.

All animals were stunned once, using a captive-bolt pistol. Each carcass was then hung from the right hind leg and exanguination was carried out with one clean cut and maximum blood spill, and was complete within an average of 60 seconds. Carcasses were dressed and then centrally-split into two sides. All carcass sides were pubic-bone (Symphysis pubis) hung (i.e. tenderstretching) and entered the chill room within 1 hour of slaughter. Chill temperature was held at approximately 10ºC for 10 hours and then at approximately 2ºC for a further 14 hours. Excision of the loin (up to 12th and/or 13th ribs) was carried out at 24 hours post-mortem, when carcass temperature had dropped below 7ºC. Muscles were individually vacuum-packed, and stored at 4ºC until relevant sampling commenced.

Proteolysis (enzyme breakdown of myofibrillar proteins) and WBSF were measured after 2, 7 and 14 days post-mortem and r-values (measurement of phosphates an indicator of energy status in muscle) were measured after 0.5, 3, 8, 24 and 48 hours post-mortem. Variances of attributes of the loin measured on the right hand side (RHS, n = 10) and left hand side (LHS, n = 10) of the carcasses were compared using Bartlett's procedure. Where variances were homogeneous, means for RHS and LHS were compared using a t-test. The relationship (R^2) between biochemical attributes and pH, WBSF, sensory tenderness and sarcomere length over the various time points post-mortem was examined by individual and stepwise multiple linear regressions on SAS (1985). Loin temperature and pH measured at intervals post-mortem were logarithmically transformed and linear regression was used to derive a cooling and pH rate of fall, respectively, for each carcass. These rates were statistically compared as above.

Results:

Comparison of the two carcass sides for chemical, quality and biochemical differences

Variances for all chemical composition and tenderness variables and biochemical attributes measured were homogenous between the LHS and RHS of the carcass (Table 5 and Table 6). Therefore, means of biochemical, chemical composition and tenderness quality from LHS and RHS were compared using a t-test. There was no significant difference between the LHS and RHS of the carcasses for of these variables.

There was a significant (P< 0.001) difference between mean

WBSF during ageing for 2, 7 or 14 days post-mortem. The semi-quantitative values for the SDS-PAGE gels found Troponin-T to actin ratio decreased significantly (P< 0.05) and the 30 kilodalton protein to actin ratio increased significantly (P< 0.001) over the 2, 7 and 14 day ageing period. This shows that there was, as expected, a significant breakdown of myofibrillar proteins over the ageing period. The r-value increased significantly (P< 0.001) over the 0.5 to 48 hours ageing period, indicating the depletion of energy resources over time.

Relationship between muscle biochemistry and the variation in tenderness
Proteolysis (30 kilodalton protein to actin ratio) after 2 days post-mortem explained 56% of the variation in WBSF after 2 days post-mortem and 40% of the variation after 7 days postmortem. Phosphate levels after 0.5 hours and 8 hours post-mortem explained 52% and 34% of the variation in sensory tenderness. Glycolytic potential explained 34% of the variation in sensory tenderness. Stepwise linear multiple regression found : 77% of the variation in WBSF after 2 days post-mortem was explained by proteolysis (30 kilodalton protein to actin ratio) after 2 days post-mortem together with phosphate level after 48 hours post-mortem; 69% of the variation in sensory tenderness was explained by differences in phosphate level and glycolytic potential measured at 0.5h post-mortem.

Intramuscular fat was the most variable quality attribute, with sarcomere length also highly variable. Within biochemical attributes, proteolysis over the 2, 7 and 14 day ageing period was the most variable attribute measured.

Steers in the present experiment and steers in experiment 2 were genetically similar and managed similarly pre- and post-slaughter using a “best practice” method. There was no difference in variance between the two experiments for any tenderness quality attributes measured.

Conclusion:

A large percentage of the variation in WBSF after 2 and 7 days post-mortem was explained by proteolysis, while a combination of proteolysis and phosphates explained WBSF after 2 days ageing.

Sensory tenderness was largely explained by phosphates and glycolytic potential. Proteolysis was the most variable biochemical attribute measured, with collagen and glycolytic potential also highly variable.

The lack of difference achieved between carcass sides emphasises the effectiveness of the control measures applied during the carcass processing. The optimum procedures applied to the animal production, carcass processing, meat conditioning and analysis of samples within the present experiment has quantified variation over the pre-, peri- and post-slaughter periods.

Table 5. Mean, standard deviation (±SD) and coefficient of variation (CV) for cold weight, pH, sarcomere length, composition and rate of pH and temperature fall of right hand side (RHS) and left hand side (LHS) of beef carcasses.

Attributes	RHS Mean (±SD)	LHS Mean (±SD)	Sig.[1]	CV%
Cold weight (kg)	185.26 (±7.95)	183.85 (±8.70)	ns	4.41
pH 2d	5.54 (±0.05)	5.54 (±0.08)	ns	3.05
Sarcomere length (mm)	2.22 (±0.31)	2.31 (±0.38)	ns	14.94
Protein (%)	22.70 (±0.39)	22.87 (±0.39)	ns	2.22
Moisture (%)	73.87 (±0.62)	74.08 (±0.81)	ns	0.96
Intramuscular fat (%)	2.31 (±0.76)	2.51 (±1.39)	ns	45.32
Rate of pH fall[2]	0.02 (±0.002)	0.02 (±0.001)	ns	–
Rate of temperature fall[3]	0.03 (±0.002)	0.03 (±0.003)	ns	–

[1]p-value of differences between variances (ns = non-significant).

[2]Rate of pH decline analysed every hour from 1 to 8 hours post-mortem.

[3]Rate of temperature decline from 1 to 24 hours post-mortem, with measurements analysed every 15 mins.

Table 6. Mean, standard deviation (±SD) and coefficient of variation (CV) for Warner Bratzler shear force (WB; newtons) after 2, 7 and 14 days ageing and sensory attributes after 14 days ageing of right hand side (RHS) and left hand side (LHS) of beef carcasses.

Attributes	RHS Mean (±SD)	LHS Mean (±SD)	Sig.[1]	CV%
WB 2d	42.11 (±5.87)	40.69 (±3.76)	ns	11.72
WB 7d	37.53 (±4.88)	36.71 (±4.67)	ns	12.58
WB 14d	32.70 (±5.97)	35.86 (±4.47)	ns	15.7
Sensory tenderness	6 (±0.78)	6 (±0.42)	ns	10.05

[1]p-value of differences between variances (ns = non-significant).

4. Acknowledgments

The authors gratefully acknowledge the considerable contribution of many colleagues to this project. Vincent McHugh together with our technical staff at Grange Research Centre provided an important, skilled contribution. Similarly, Grange farm and service staff willingly undertook considerable work in the animal-related research in this project.

Many parts of the work in this report involved fruitful collaboration with other Teagasc research colleagues, in particular Gerry Keane and Michael Drennan at Grange Research Centre and Declan Troy at the National Food Centre. The assistance and willing co-operation of the management and staff at Meadowmeats, Rathdowney, Co. Laois is greatly appreciated.

5. Publications from this project

Maher, S.C., Mullen, A.M., Moloney, A.P. and Buckley, D.J. (2001). Variation in the eating quality of Irish beef. (Abstract) *Irish Journal of Agricultural and Food Research,* 40: 133 – 134.

Maher, S.C., Mullen, A.M., Moloney, A.P., Buckley, J. and Kerry, J.P. (2001). Variation in the eating quality of Irish beef as a result of post slaughter handling. In: Proceedings *47th International Congress of Meat Science and Technology, Cracow, Poland,* 224-225.

Maher, S.C., LeGoff, M., Mullen, A.M., Moloney, A.P., Drennan, M.J., Buckley, J. and Kerry, J.P. (2002). Tenderness, composition and eating quality of beef from progeny of two charolais sires. In: Proceedings *Agricultural Research Forum,* Tullamore, p79.

Maher, S.C., Moloney, A.P., Mullen, A.M., Reville, W., Buckley, D.J., Kerry, J.P. and Troy, D.J. (2002). The relationship between extreme sarcomere lengths and tenderness of bovine steer M. *longissimus dorsi*. In: Proceedings *48th International Conference of Meat Science and Technology, Rome, Italy,* 228-229.

Maher, S.C., Moloney, A.P., Mullen, A.M., Reville, W., Buckley, D.J., Kerry, J.P. and Troy, D.J. (2002). Does sarcomere length affect tenderness from steer M. *longissimus dorsi*. In: Proceedings *Walsh Fellowship Seminar, Teagasc*, Dublin 12.

Maher, S.C., Mullen, A.M., Moloney, A.P., Buckley, D.J., Kerry, J.P., Keane, M.G. and Dunne, P.G. (2002). The influence of dairy and beef x dairy cattle on tenderness and colour of beef. (Abstract) *Irish Journal of Agricultural and Food Research,* 41: 154-155.

Maher, S.C., Mullen, A.M., Moloney, A.P., Troy, D.J., Buckley, D J. and Kerry, J.P. (2003). The relationship between extreme sarcomere lengths and tenderness of bovine steer M. *longissimus dorsi.* (Abstract) *Irish Journal of Agricultural and Food Research* 42: 159.

Maher, S.C., Mullen, A.M., Moloney, A.P., Buckley, D.J. and Kerry J.P. (2003). Decreasing variation in the eating quality of beef by controlling genetics and pre- and post-slaughter management. (Abstract) *Irish Journal of Agricultural and Food Research* 42: 141.

Maher, S.C., Moloney, A.P., Mullen, A.M., Keane, M.G., Buckley, D.J. and Kerry, J.P. (2003). Decreasing variation in tenderness of beef by controlling pre- and post-slaughter management. In: Proceedings *Agricultural Research Forum,* Tullamore, p43.

Maher, S.C. (2003). Quantifying variation in the eating quality of beef – with an emphasis on tenderness. Ph.D. dissertation, National University of Ireland, Cork

Maher, S.C., Mullen, A.M., Moloney, A.P., Buckley, D.J. and Kerry, J.P. (2004). Quantifying the extent of variation in the eating quality traits of the M. *longissimus dorsi* and M. *semimembranosus* of conventionally processed Irish beef. *Meat Science* 66: 351-360.

Maher, S.C., Mullen, A.M., Moloney, A.P., Drennan, D.J., Buckley, D.J. and Kerry, J.P. (2004). Colour, composition and eating quality of beef from the progeny of two Charolais sires. *Meat Science* 67: 73-80.

Maher, S.C., Mullen, A.M., Keane, M.G., Buckley, D.J., Kerry, J.P. and Moloney, A.P. (2004). Decreasing variation in the eating quality of beef through homogenous pre-and post–slaughter management. *Meat Science* 67: 33-34.

Maher, S.C, Mullen, A.M, Keane, M.G., Buckley, D.J, Kerry , J.P. and Moloney, A.P. (2004). Variation in the eating quality of M. *longissimus dorsi* from Holstein-Friesian bulls and steers of New Zealand and European/American descent, and Belgian Blue and Holstein-Friesians slaughered at two weights. *Livestock Production Science* 90: 271-277.

Maher, S.C., Mullen, A.M., Buckley, D.J., Kerry, J.P., Troy, D.J. and Moloney, A.P. (2005). The influence of biochemical differences on the variation in the tenderness of *M. longissimus dorsi* of Belgian Blue steers managed homogenously pre and post-slaughter. *Meat Science* (69: 215-224).

Maher, S.C., Mullen, A.M., Moloney, A.P., Reville, W.S., Buckley, P.J., Kerry, J.P. and Troy, D.J. (2005). Ultrastructural variation in beef *M. longissimus dorsi* as an explanation of the variation in beef tenderness. *Irish Journal of Agricultural and Food Research* (submitted for publication).