The Science of Beef Quality

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This is the second in a series of three joint meetings on meat quality held by the British Society of Animal Science, the University of Bristol, the Agricultural University of Krakow and the Hellenic Society of Animal Production.

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THE SCIENCE OF BEEF QUALITY

The papers in these Proceedings of BSAS are those presented at the "Science of Beef Quality" Conference held at the University of Bristol's School of Clinical Veterinary Science on 18/19 May 2005.

The meeting brought together researchers from around the world to present their latest findings on different aspects of beef quality. How these findings can be applied in the beef industry and how beef will be produced and marketed in the future were also topics debated at the meeting and included in these Proceedings.

A theme running through many of the papers is that production and processing factors are both important for eventual beef quality. Good collaboration between partners in the beef chain is therefore needed for the level of quality to be reliably high.

This conference on beef quality is the second in a series of three conferences on meat quality organised by BSAS. The first was on pork (Poland, October 2004) and the third will be on Sheepmeat to be held in Athens, Greece in 2006.

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The Science of Beef Quality

Contents

Effect of beef systems on meat composition and quality

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Introduction The fatty acid composition of ruminant products has become increasingly important in recent years, because of the association between the fatty acid composition of dietary fat (and in particular saturated fats) and cardiovascular and other lifestyle diseases in humans. Dietary advice in Europe is to decrease the fat content of the diet, maintain the ratio of the polyunsaturated to saturated fatty acids (P:S) at about 0.4 and to increase the intake of n-3 polyunsaturated fatty acids (PUFA) relative to n-6 PUFA (WHO, 2003). The latter recommendation seeks to address the large increase in n-6 at the expense of n-3 PUFA which has occurred from the Palaeolithic period to the present time. Currently, the n-6:n-3 PUFA value is approximately 15:1 in Western Europe and USA, whereas during our evolution it was 1:1 or less (Simopoulos, 2001; Leaf *et al*. 2003). Although it is the fat content and fatty acid composition of the whole diet, which is important, research effort has focused on changing individual foods to make them more compatible with these guidelines.

The processes of lipolysis and biohydrogenation in the rumen, which result in the conversion dietary PUFA to more saturated end products, are major reasons why ruminant fats are highly saturated in nature. However, this biohydrogenation is also responsible for ruminant fats being the major source of conjugated linoleic acid (CLA), a range of *cis* and *trans* conjugated isomers of octadecadienoic acid, some with important anticarcinogenic or antiatherogenic activities. Understanding the events surrounding fatty acid metabolism in the rumen is central to the development of effective strategies to manipulate the fatty acid composition of beef.

Increasing PUFA in ruminant tissues increases the susceptibility to oxidative breakdown of muscle lipid during conditioning and retail display. A high degree of oxidation changes flavour and promotes muscle pigment oxidation, which reduces shelf life. However, some oxidation is required for optimum flavour development in beef. The extent of lipid oxidation is limited by antioxidants in tissues. These antioxidants include vitamin E (either added to the diet or present naturally) and other phenolic compounds from the diet.

This paper reviews strategies (nutritional and genetic) to enhance the nutritional value of beef by increasing its content of n-3 PUFA and conjugated linoleic acid (CLA). The implications for meat quality, in particular colour shelf life and sensory attributes, are discussed.

Fatty acid composition of beef Lean beef has an intramuscular fat content of around 5% or less with approximately 47, 42 and 4% of total fatty acids as saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and PUFA, respectively. The P:S ratio for beef is typically low at around 0.1 (Scollan *et al*., 2001), except for double muscled animals which are very lean (<1% intramuscular fat) were the P:S ratio is typically 0.5-0.7 (Raes *et al*., 2004). The n-6:n-3 ratio for beef is beneficially low, typically less than 3. This reflects the considerable amounts of n-3 PUFA in beef, particularly α-linolenic acid (18:3n-*3*) and the long chain PUFA, eicosapentaenoic acid (20:5*n-3,* EPA) and, docosahexaenoic acid (22:6n-*3,* DHA). The predominant SFA are 14:0, 16:0 and 18:0. Of the total SFA, 0.3 are represented by stearic acid (18:0). SFA are recognised to influence plasma cholesterol, though 18:0 is regarded as neutral in this regard and 16:0 is not hypercholesterolemic if the diet contains high levels of linoleic acid (18:2n-6; Clandinin *et al*. 2000; Yu *et al*. 1995). Myristic acid (14:0) is regarded as more potent than palmitic acid (16:0) in raising plasma lipids (Zock *et al*. 1994). Linoleic and a-linolenic acids are the main PUFA while oleic acid (18:1n-9) is the most prominent MUFA, with the remainder of the MUFA occurring mainly as *cis*and *trans* isomers of 18:1. The PUFA and MUFA are generally regarded as beneficial for human health and there is recent evidence of beneficial effects of 18:1 *trans*-11 (Corl *et al*. 2003), though other work suggests negative effects (Clifton *et al*. 2004). The main CLA isomer in beef is *cis*-9, *trans*-11 representing 72-90 % of total CLA isomers. Dannenberger et al. (2004) reported 10 isomers of CLA in beef with *cis*-9, *trans*-11 CLA representing approximately 70% of total CLA isomers. The *trans*-11, *cis*-13, *trans*-7, *cis*-9, and *trans*-10, *cis*-12 isomers represent approximately 9, 8 and 2 % of total CLA isomers, respectively. Biological effects of two of these isomers, *cis*-9, *trans*-11 and *trans*-10, *cis*-12 CLA, have been extensively investigated and anticarcinogenic and antiatherogenic effects of *cis*-9, *trans*-11 and the anti-obesity effects of *trans*-10, *cis*-12 have been documented.

Important sources of dietary fatty acids The most effective method of manipulating the fatty acid composition of beef is by dietary inclusion of ingredients, which are known sources of long chain PUFA. These include forages and a range of oils and oil seeds. Forages, such as grass are rich in α-linolenic acid, which typically ranges between 50-75% of total lipid. Oilseeds differ widely in the fatty acid composition of their lipid but usually one fatty acid is predominant. Rapeseed, soybean and linseed are rich in oleic, linoleic and linolenic acids, respectively, and feeding animals on these products generally results in increases in the corresponding fatty acid in beef. Fish oils are rich in the long chain PUFA, EPA and DHA. However, the way in which the lipid is offered to the animal (for example, as the oil or whole oilseed) may have an important effect on the degree of response.

Feed effects on fatty acids in beef Feeding linseed or linseed oil in a concentrate resulted in increases in 18:3n-3 and 20:5n-3 but not 22:6n-3 in tissues (Scollan *et al*. 2001; Raes *et al*. 2004). This contributed towards beneficial reductions in the n-6:n-3 ratio but had no impact on the P:S ratio. In general, dietary manipulation does not increase the P:S ratio in the meat above the 0.06-0.15 normally observed. This relates to the high degree of biohydrogenation of dietary PUFA in the rumen. Recent studies in France have demonstrated that by providing 18:3n-3 as linseed oil directly into the small intestine, hence bypassing the very effective hydrogenating powers of the rumen micro-organisms, high levels of PUFA may be incorporated into beef muscle (Gatellier *et al*. 2004). Relative to a control diet (C) feeding linseed (L) in the diet increased 18:3n-3 in muscle by approximately 1.5-2.0 fold. However, infusing an equivalent amount of 18:3n-3 (as linseed oil, LO) into the small intestine increased the percentage and amount (mg/100 g muscle) of 18:3n-3 in total lipid to 1.0, 1.5 and 8.7 and 15.8, 26.3 and 176.5 for diets C, L and LO, respectively. The LO treatment resulted in a high P:S ratio (0.495 relative to the recommended target of > 0.4) and a low n-6:n-3 ratio (1.04 relative to the recommended target of < 2-3).

Effective ruminal protection of dietary fatty acids, such as that provided by encapsulation of PUFA in formaldehyde-treated protein has been adopted to help ameliorate low P:S ratios. This product resists proteolysis in the rumen and thereby protects the polyunsaturated oil droplets against microbial hydrogenation. In the acidic secretions of the abomasum, however, the formaldehyde-protein complex is hydrolysed, thus making the PUFA available for digestion and absorption in the small intestine. Using this methodology, Scollan *et al*. (2003), found that relative to the control diet, feeding a ruminally protected lipid (PLS; made from soya bean, linseed and sunflower oils mixed to give a 2.4:1 ratio of 18:2n-6:18:3n-3) resulted in meat characterised by a higher content of both 18:2n-6 and 18:3n-3 and a higher P:S ratio. However, this study was less successful in improving the n-6:n-3 ratio. This relates to the competition between n-6 and n-3 PUFA for deposition in muscle lipids (in particular in phospholipids). This work helped to focus attention on the importance of the ratio of n-6:n-3 in the PLS in optimising the balance of fatty acids deposited. A further study investigated the effect of feeding a PLS with a lower n-6:n-3 ratio (Scollan *et al*., 2004). Charolais steers were fed on ad libitum grass silage plus one of four concentrates in which the lipid source was either Megalac (Mega, rich in palmitic acid; 16:0) or PLS (soya bean, linseed and sunflower oils resulting in a 1.1:1 ratio of 18:2n-6:18:3n-3): concentrate 1, (Mega, control) contained 139g/kg Mega; concentrate 2, (PLS1) contained 67g/kg Mega with 400 g/d PLS fed separately; concentrate 3, (PLS2) contained 24g/kg Mega with 800 g/d PLS fed separately, concentrate 4, (PLS3) contained no Mega and 1000 g/d PLS fed separately. On average, feeding PLS increased the content of 18:2n-6 and 18:3n-3 by a factor of 2.3 and 4.2, respectively.. The content of 20:5n-3 (EPA; synthesised from 18:3n-3), was increased by the PLS. The P:S was increased while the n-6:n-3 ratio was reduced with inclusion of PLS. Hence, feeding a protected lipid supplement with a n-6:n-3 ratio of 1.1:1 compared to 2.4:1 (Scollan *et al*. 2003) resulted in a much lower n-6:n-3 ratio in the meat (1.88 v 3.59, respectively).

Feeding pasture rich in 18:3n-3 relative to concentrates rich in 18:2n-6, results in higher concentrations of n-3 PUFA in muscle lipids (Dannenberger *et al*., 2004). Grass relative to concentrate feeding not only increased 18:3n-3 in muscle phospholipids but also EPA and DHA. Concentrates rich in 18:2n-6 lead to higher concentrations of 18:2n-6 and associated longer chain derivatives (20:4n-6). French et al. (2000a) found that an increase in the proportion of grass in the diet decreased the concentration of SFA, increased P:S and n-3 PUFA concentration and decreased n-6:n-3 PUFA.

There is much interest in CLA. Studies have confirmed that the main CLA isomer in beef is *cis*-9, *trans*-11 and is mainly associated with the neutral lipid fraction (typically 92% of total CLA in muscle lipid) and hence is positively correlated with degree of fatness. It is also established that the majority of CLA found in muscle is synthesised from 18:1*trans*-11 (vaccenic acid, TVA) via delta-9 desaturase in the tissue rather than directly from the rumen. In general, feeding PUFA rich diets (i.e. sunflower oil, soya, linseed or fish oil) results in increases in tissue CLA (Mir *et al*. 2003). Pasture feeding also results in higher CLA and there is a positive association between tissue CLA content and duration at pasture before slaughter (Noci *et al*. 2004).

Breed effects on fatty acids in beef Breeds may also differ in their fat composition (both total intramuscular fat and individual fatty acids) of beef. The fatty acid composition of beef is influenced by genetic factors although to a lower extent than dietary factors. Though these breed differences are generally small, they nevertheless reflect differences in underlying gene expression or enzymes involved in fatty acid synthesis, and therefore merit attention. There is a strong negative exponential relationship between fatness and P:S ratio. As the content of SFA and MUFA increase faster with increasing fatness than does the content of PUFA, the relative proportion of PUFA and the P:S ratio decrease with increasing fatness. We have compared Holstein-Friesian (dairy) *v*. Welsh Black (traditional beef animals) and found that total muscle fatty acids were higher in Holstein-Friesians than Welsh Blacks. The content of the beneficial PUFA, EPA, was 20% higher in Welsh Black (Choi *et al*. 2000). When expressed as a proportion of the total fatty acids, *n*-3 linolenic acid as well as EPA was higher in the Welsh Black, resulting in improved P:S and *n*-6:*n*-3 ratios.

Rumen lipolysis and biohydrogenation Dietary PUFA are rapidly hydrogenated in the rumen by microbes, resulting in the production of SFA (principally stearic acid, 18:0) but also in the formation of CLA and trans monoene intermediates. This is one of the main reasons why ruminant fats are highly saturated. The extent to which biohydrogenation is "complete" influences the amount of SFA produced in the rumen but also the amount of CLA and TVA. The extent of biohydrogenation of dietary PUFA from a range of different feed types, including forages, is very high, averaging approximately 86 and 92% for 18:2n-6 and 18:3n-3, respectively. For forages, the exception is red clover. Recent studies at IGER have noted higher levels of PUFA in meat (Scollan *et al*. unpublished) from animals fed on red clover-based diets which has been associated with a lower degree of ruminal biohydrogenation. Red clover contains the enzyme polyphenol oxidase (PPO) which is activated when red clover tissue is damaged, reducing the extent of lipolysis (Lee *et al.* 2004). Understanding and developing methods of altering lipolysis and biohydrogenation of dietary PUFA in the rumen is essential in terms of providing new opportunities for enhancing the fatty acid composition of beef and other ruminant products.

Beef fatty acids and meat quality Increasing PUFA in ruminant tissues increases the susceptibility to oxidative breakdown of muscle lipid during conditioning and retail display. High oxidation changes flavour and promotes muscle pigment oxidation, which reduces shelf life (Wood *et al*. 2003). The extent of lipid oxidation is limited by the presence in tissue of antioxidants including vitamin E (either added to the diet or present naturally) and other phenolic compounds from the diet with antioxidant activity.

Feeding steers on a concentrate containing fish oil resulted in muscle that had significantly higher levels of TBA (thiobarbituric acid-reacting substances, a measure of lipid oxidation) than those fed concentrates containing megalac or linseed at 4, 8 and 11 days of simulated retail display (Vatansever *et al*. 2000). This muscle also showed greater colour deterioration and had lower vitamin E in muscle than that from steers fed on megalac, due to its greater utilisation in the more unsaturated membrane lipids. Associated taste panel studies gave lower scores for overall liking for meat from animals fed on diets containing fish oil. Interestingly in this work, feeding linseed which resulted in a linolenic acid content of 1.2% of total lipids had no negative effects on quality characteristics. However, when increasing the content of linolenic acid in the meat further to 2.8% of total lipid, by using ruminally protected lipids, sensory scores for "abnormal" and "rancid" were recorded (Scollan *et al*. 2004). These results support the conclusion by Wood *et al*. (2003) that only when concentrations of linolenic acid approach 3% of lipids are there any adverse effects on lipid stability, colour stability or flavour.

Pasture feeding does result in higher concentrations of more oxidisable *n*-3 PUFA in muscle lipids, but the meat is more resistant to lipid oxidation than concentrate (grain) fed-beef. Warren *et al*. (2002) examined the feeding of Holstein-Friesian and Aberdeen Angus steers with diets based on grass silage or concentrate. TBA values were four and six times higher in steaks from concentrate-fed animals compared with the equivalent silage-fed animals after 4 and 7d of retail display, respectively. Steaks from silage-fed animals had a retail colour shelf-life 5d longer than that of steaks from concentrate-fed animals at 11 and 6d, respectively. These effects were related to higher levels of vitamin E in the meat from grass silage-fed animals (Richardson et al., 2004). However, there is some evidence that the benefits of pasture feeding may not hold for meat which is further processed by mincing (Realini *et al*. 2004).

The differences in the fatty acid composition of meat induced by feeding grass compared to concentrates have been reported to affect beef flavour. Larick and Turner (1990) showed that the scores for flavour descriptors changed when cattle previously grass-fed were changed to a maize diet in a feedlot. As the period of maize feeding increased the concentration of 18:3*n*-3 in muscle phospholipid declined and that of 18:2*n*-6 increased and flavours identified as "sweet" and "gamey" declined, whereas "sour", "blood like" and "cooked beef fat" increased. Flavour chemists have demonstrated that lipid breakdown products such as aldehydes and ketones help to explain these flavour differences (Larick et al., 1987). However, taste panellists in Ireland (French *et al*. 2000b) and in Canada (McCaughey and Cliplet 1996) found no difference in the flavour of grass and grain-fed beef. The authors suggested this was due to higher antioxidant concentrations, limiting lipid oxidation reactions and the production of "off-flavours" in the grass used in these studies.

In recent Bristol – IGER research, Warren *et al*. (2002) found that feeding grass silage produced higher beef flavour intensity in loin steaks as identified by the trained taste panel in comparison with a concentrate – based diet. There was also lower abnormal flavour intensity after grass feeding and this was apparent in topside roasts and also minced beef as well as in loin steaks. Meat from grass silage-fed animals had a slightly higher "livery" note, which seems characteristic of grass feeding.

Recent studies at IGER have provided evidence that feeding beef cattle on red clover compared to grass silage based diets produced meat with reduced colour shelf life (Scollan *et al*. unpublished). The latter was related to lower levels of vitamin E in the muscle. Feeding supplemental vitamin E along with the red clover corrected the problem.

Conclusions Beef may be produced which is more compatible with current medical guidelines for the composition of the human diet than that which is currently available Studies have demonstrated that beef is low fat (less than 5%) and that nutritional opportunities exist to produce beef characterised by a lower content of atherogenic saturated fatty acids, higher content of more beneficial monounsaturated fatty acids and polyunsaturated fatty acids and lower n-6:n-3 PUFA ratio. It is difficult to have a large shift in the P:S ratio by conventional nutritional means due to the high degree of biohydrogenation of dietary PUFA in the rumen. Studies which provided PUFA either post ruminally by direct infusion into small intestine or by using ruminally protected lipids confirmed that beef muscle does have a high capacity to incorporate beneficial PUFA in its lipids resulting in meat characterised by a high P:S ratio and low n-6:n-3 ratio. Important relationships exist between the fatty acid composition of meat and it's sensory attributes and colour shelf life. As the content of *n*-3 PUFA in the meat are increased to around 3%, sensory attributes such as "greasy" and "fishy" score higher and colour shelf life may be reduced. Under these situations high levels of dietary antioxidant are necessary to help stabilise the long chain PUFA so that high nutritional and sensory quality are obtained.

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Issues affecting beef production in Poland

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Introduction The purpose of this paper is to present a case study of the beef sector in Poland, the country being in an important economic and political transition.

Poland, a relatively large European country, with nearly 40 million people and over 300.000 square kilometers of land, has undergone revolutionary changes in the last few years, from central planning to a free market economy.
Entering the European Union, Poland brings great agricultural production potential, only partly exploited till now, and, on the other hand, great market possibilities.

However, it brings also a problem of about 2 million small farms with an average size of 7 hectares, a problem of about 30 per cent of population employed in agriculture, and 25 per cent of unemployment in rural areas, and, what is very important, Polish people joined the EU on the basis of expectations that their life will improve.
The Common Agricultural Policy of the EU, especially before its reform, was the basis of great hopes for Polish farmers.

Having in mind these few words of general introduction let us look more specifically at the problems of the beef sector.

Cattle population Black and white cattle of a dual purpose type dominated for long in Poland with marginal numbers of other breeds. Recently, semen and bulls of the Holstein-Frisian breed were intensively used with a significant increase in average milk yield. Now in Poland, the average milk production per cow is 4100 kg.

Specialized beef breeds were only recently introduced to Poland. Since the 1990's a number of purebred cattle, mainly Limousin, Charolais, and Hereford were imported. In 1992 the Beef Cattle Association was organized and the herdbooks opened. After accession to EU the interest for breeding of beef cattle increased substantially in Poland. At present there are about 20 thousand females registered in beef cattle herdbooks.

Cross breeding by using semen of beef bulls to inseminate dairy cows has been widely used for many years. Now about 0.5 million dairy cows are inseminated using beef bulls' semen.

During the last 15 years the number of cattle in Poland has dropped from 10.7 million to 5.4 million. It means that the number of cattle per 100 ha of agricultural land dwindled at that time from 50 to 33. Just compare it with Germany where there are 83 head of cattle per 100 ha.

The reason for such a drastic reduction of the cattle population in Poland (the trend is still down) is a complex one. In 1989 the state farms had been drastically abolished. The small farms were gradually eliminated from milk production (quality requirements, transport etc.), and the local demand for beef and milk dropped because of low income. Total profitability of the cattle sector was in general low.

Scale of production On a parallel with cattle numbers, the beef production in Poland also fell. From 1989 till 2003 beef production (in live weight) dropped from 1.25 million tons to 0,59 million tons. Number of slaughtered animals dropped from 3,3.in 1989 to 1.37 million head. The average live weight of slaughtered cattle is now 427 kg . These are dramatic reductions. What is significant, however, is the fact that even this reduced cattle number is at present not fully exploited for beef production. For example, out of 2.2 million calves born annually, close to 1 million is either slaughtered at a young age or exported live for fattening in the EU-15, with Italy being the largest importer.

Annually, about 0,5 million live calves of average weight of about 100 kg are exported to other countries. Still-existing subsidies for slaughtered young bulls and steers (in spite of CAP reform)in some of the EU-15 member countries give us no hope for a quick change of this situation.

Production systems As was mentioned, Poles traditionally used to consume beef of culled dairy cows and veal of very young calves slaughtered at 40-60 kg of live weight. Starting from the seventies the consumption of veal was falling due to profitable export of live calves and young cattle to EU for further fattening. Due to special customs policy of EU Poland could export only live cattle up to 350 kg live weight for which there were licensed limits, and only small amounts of carcasses. This was a main factor why feedlots are at present practically unknown in Poland and fattening of bulls up to 500-600 kg does not exist on a large scale.

Such a situation was influenced by EU import policy before enlargement, on the one hand, and by a lack of national demand for good quality beef, on the other. Strange enough, such a situation also exists now due to the fact that a number of EU-15 members still apply direct payments for fattened bulls in spite of CAP reform. This creates a very high demand in Poland for young calves to be exported live. At present the export prices for young calves amount up to 2,5 euro per kg live weight, whereas, for 500 kg live weight bulls the price is 1,2 euro. No surprise that the majority of male calves including black and whites, are still exported to the EU-15 countries.

State subsidies Starting from 1992 the state subsidies for beef cattle breeding development amounted to 100 euro per registered cow and 170 euro per purebred bull qualified for reproduction. These subsidies are now drastically reduced and, in the near future, they may be cancelled altogether.

Terms of trade In Poland there exist quite modern slaughterhouses and a meat processing industry with underutilized capacity. However, the trade of animals for slaughter is being done in a very traditional even archaic way. For cattle, auctions are practically unknown, and even large slaughterhouses are purchasing animals through a network of middlemen. The majority of cattle for slaughter and for export are being purchased on the basis of live weight, frequently by eye.

The EUROP system of carcass classification is known in Poland but is not obligatory and seldom implemented.

Local markets Whereas total meat consumption in Poland is now 73 kg per capita a year, consumption of beef was reduced during the last decade from 17 kg to 5 kg . This dramatic reduction is mainly due to reduced purchasing power of consumers. Poles have no tradition of quality beef consumption. Pork dominated the diet followed by poultry which replaced recently expensive beef. Mutton and lamb consumption is negligible.

International Trade Poland is a net exporter of beef with a net balance of 80,000 tons (in carcass equivalent). About 50% of total export (in carcass equivalent) are live animals. In numbers of total exported live animals, the calves up to 80 kg of live weight participated in 78 per cent, young cattle of 80-160 kg live weight in 17 per cent, and cattle over 300 kg of live weight shared in 5 per cent.

After joining European Union In general, our entry to the EU improved the situation in the Polish beef sector.
First of all, the prices for beef have increased. Whereas, before enlargement the prices for slaughtered animals in Poland were half as high as in the EU, now they are about 60-70 per cent.

As you know during negotiations we agreed to the reduced payments from CAP and accepted the system of direct payments depending on the number of hectares. This, of course, does not stimulate the production increase and means full decoupling. This fact has a special meaning for Poland due to the reduction in the cattle population and beef production by more than a half during the last 15 years.

Let me show what I have in mind by the following comparison. In Poland there are 5,4 million cattle, 16,8 million ha of arable land and annual beef production (carcass) is 320 thousand tons. In Italy the number of cattle is 6,8 million, arable land 15,6 million ha but beef production (carcass) is 1.128 thousand tons. Italy in comparison with Poland has 126 per cent of cattle, 93 per cent of arable land but produces 3,5 times as much of beef. No doubt, decoupling means something different for Italy than for Poland.

By maintaining direct payments, after CAP reform, for slaughter animals and nursing cows in many EU-15 countries the Polish ability to compete on the beef European market was strongly harmed. As a result, Poland is now full of middlemen actively penetrating Polish villages in search of calves to be exported to Italy, Germany, France, Greece and Spain. Specially favoured and paid best are the calves of about 100 kg of live weight, and it takes place under the abundance of unutilized land and labour in Polish villages. In EU-15, as we know, the shortage of beef grows. This would create a good future for Poland provided CAP will return to uniformity and equal treatment of member countries occurs. We are looking forward with hope that the feedlots for beef cattle will appear in Poland again. The other reason for optimism for Polish beef production is the potential for a substantial increase in local beef consumption, which will undoubtedly come with the increase of standard of living of our citizens.

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Evaluating video image analysis (VIA) systems for beef carcass classification

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Introduction. The EU beef carcass classification scheme involves the visual assessment of conformation and fatness. Some see this as lacking in objectivity. Machines that use Video Image Analysis (VIA) technology have been developed to objectively assess the same criteria. After a long delay the EU finally accepted that such machines were as accurate as human graders and in 2003 the regulations were changed to allow their use. These machines have advantages over and above their objectivity and consistency as they can also assess saleable yield, which is closer to the realisable value of a carcass.

This paper will describe the VIA systems, explain how they work and describe trials carried out in Ireland to evaluate their performance.

The EU beef carcass classification scheme. European Union regulations state that beef carcasses must be classified according to their conformation and fat cover (EC 1208/1981), the so-called EUROP system. For conformation the classes E U R O P are used with E denoting carcasses with the best conformation. There is an option to use an extra S class for carcasses with extremely good muscle development such as double-muscled individuals. Fat cover is assessed on a five-point scale using the numbers 1-5. Many countries subdivide each of the categories for conformation and fat into 3 subclasses to give a 15 x 15 grid. In other countries, such as Ireland and the UK, the most common fat class or classes are sub-divided into L (Low) and H (High) and some of the conformation classes are subdivided. The classes each have descriptions and photographic standards. Classifiers are highly trained and must be regularly monitored and retrained if necessary. Standards throughout the EU are maintained by an expert panel who visit each country on a regular basis to check that the grading is in line with the EU standards. The classification scheme is used by the EU for price reporting, market intervention purposes and by the industry for quality-based payments to producers and carcass trading. In July 2003 the regulation was changed to allow mechanical grading systems to be used provided they were sufficiently accurate (EC 1215/2003). This contains the rules for carrying out authorisation trials and the statistical criteria that must be met. In 2004 Ireland became the first country to have VIA systems authorised and 24 systems are now in operation.

How do VIA systems work? Video Image Analysis (VIA) systems use cameras to capture images of a carcass and a computer to collect data – lengths, areas, volumes, angles, colours etc.- and to use these data to predict the conformation, fat class and saleable meat yield. The development of these systems has been reviewed by Allen (2003). Five VIA systems have been developed and are commercially available:

BCC2 was developed by SFK technology in Denmark. This uses a single colour camera, a holding frame to keep the half carcass steady, a lighting system and striped lighting. Three images of the outer side of the half carcass are taken while it is stationary – one with the lights on, another with them off and a third with the striped light. The first two are subtracted from each other to take account of any variation in ambient light. The third is used to gain 3D information about the carcass from the degree of curvature of the stripes.

VBS2000 was developed by E + V in Germany. This also uses a single colour camera, a holding frame to keep the half carcass steady, a lighting system and striped lighting. Only two images are taken, as it is not considered necessary to adjust for ambient light.

Normaclass was developed by Normaclass in France for the industry organisation, INTERBEV. This uses six monochrome cameras set at different heights and viewing angles and a rotating dual holding frame. The first half carcass rests against the frame rib side out and is imaged by two of the cameras (one for the hind the other for the fore). These images are used to determine the outline of the carcass and to assess the fat on the inside. The table then rotates 180 degrees, the first side is released and the frame is washed by an automatic system operated by pneumatic pistons. The second half carcass then comes to rest against the other frame. This side is moved into three different positions and all six cameras take images at each orientation. 3D information is gained from these different viewing angles rather than from striped light.
VIAScan was developed by Meat and Livestock Australia in Australia. This system does not have a holding frame. It takes pictures with a colour camera while the half carcass is moving so it can operate at much higher speeds. The camera, lighting system and computer are all contained in a stainless steel box. The system is the most compact and is placed only about half as far from the line as the others.

CVS was developed by Lacombe University in Canada. It is very similar to VIAScan. It also operates at high line speeds as it doesn't stop the half carcass.

A comparative trial of three VIA systems. In 1999 the Irish beef industry were interested in automated grading, as they felt that the improved objectivity would benefit both producers and processors. Teagasc were commissioned to carry out a trial of available systems and to make recommendations about their accuracy. Three systems were selected and installed side by side on the kill line at Meadow Meats in Midleton, County Cork. A team of three experienced classifiers scored carcasses independently for conformation and fat class using a 15 x 15 grid (i.e. all classes divided into 3). If they did not all agree there was a discussion and a consensus was agreed. This was the reference classification. Each of the three systems then took images of the half carcasses and stored the data. Data were captured for over 7,000 carcasses and these were divided into calibration (4,278) and validation (2,969) sets. The machines were calibrated with the reference scores for the calibration set then they gave predicted scores for the validation set. The predictions were analysed as deviations from the reference score and the percentage of predicted scores either agreeing with the reference or deviating by one subclass (correspondence) was calculated.

The percentage correspondence for conformation was 92.8, 91.0 and 96.5 for BCC2, VIAscan and VBS200, respectively. For conformation there were biases towards underscoring by BCC2 and towards overscoring by VIAscan. All systems had the lowest correspondence for U carcasses and performed more consistently across fat classes. With regard to sex category, all systems had the highest correspondence for cows and the lowest for steers. Also, all systems performed better on light than on heavy carcasses.

For fat class the percentage correspondence was 80.4, 72.0 and 74.8 for BCC2, VIAscan and VBS200, respectively. Biases were much smaller than for conformation for all systems, though BCC2 tended to underscore for fat class. BCC2 and VIAscan had a higher percentage correspondence for lean and fat carcasses, whereas the performance of VBS2000 was more consistent over the fat classes. The performance of all systems was consistent across conformation classes. All systems performed equally well for the three sex categories and for light and heavy carcasses.

There was evidence that the systems were not optimally calibrated for Irish carcasses, so a second trial was carried out in the spring of 2000. All the reference scores from the first trial were used to recalibrate the systems prior to this trail, which was organised in an identical way to the first trial except that the systems gave predictions on the day for all carcasses. The percentage correspondence for conformation predictions was either the same (VBS2000 = 95.4) or slightly better (BCC2 = 97.0; VIAscan = 94.2), though there were still biases, with BCC2 again underscoring and VBS2000 overscoring. The performance for fat class predictions was either the same (BCC2 = 79.6; VBS2000 = 74.4) or better (VIAscan = 76.1), though VIAscan tended to underscore and VBS2000 tended to overscore. A detailed report of the two trials (Allen and Finnerty, 2000) and a shorter summary (Allen and Finnerty, 2001) have been published.

Authorisation trial. In 2003 after the regulation had been amended to allow automated grading an authorisation trial was carried out on the same three systems at the same factory. Following the EC regulation a panel of five classifiers, three from other EU countries, was used and a representative sample of 600 carcasses were classified independently by each classifier and by the three VIA systems. The median result of the panel was taken as the reference and the predictions of the systems were compared with this. Scores were allocated as shown in Table 1 and all three systems passed the 600-point threshold for authorisation. They also passed the bias and slope limits shown in the table.

Table 1 Scoring system for authorisation of automated grading equipment

	Conformation	Fat cover
No error	10	10
Error of 1 subclass	6	6
Error of 2 subclasses	-9	0
Error of 3 subclasses	-27	-13
Error of more than 3 subclasses	-48	-30
Total score	>600	>600
Bias	± 0.3	± 0.60
Slope of the regression line	1 ± 0.15	1 ± 0.30

There is a recognition in the scoring system that fat cover is more difficult to assess than conformation. The results from the comparative trail in Ireland and all other published research on VIA systems indicate that both classifiers and automated systems are less accurate at assessing fat cover than conformation. This may be because on fatter carcasses the depth of fat becomes important in addition to the total area of the carcass covered by fat and the depth is difficult to visualise. It should be noted that if classifiers have more difficulty in assessing fat cover than so will the automated systems as these are calibrated against classifiers. Whatever the reason the scoring system imposes lower penalties for fat cover than for conformation while retaining the same threshold of 600 points.

Saleable yield prediction by VIA. Apart from their objectivity at assessing EUROP grades, VIA systems have the further advantage of being able to predict saleable yield. Borgaard et al. (1996) showed that the BCC-2 was more accurate than a classifier in predicting the percentage saleable yield (SEP = 1.34 v 1.63), the percentage hindquarter (SEP = 1.01 v 1.26) and the ribeye area (SEP = 5.8 v 6.7). VIAscan was shown to be more accurate at predicting saleable yield than the existing grading system that used weight and a fat depth for three out of our types of carcasses (Ferguson et al., 1995). Standard errors for the VIAscan were between 0.98 and 1.52%. Sonnichsen et al. (1998)

reported a slightly higher SEP of 1.8% for predicting the saleable yield of 301 young bulls of three breeds. However, it is not meaningful to compare the results of different trials due to differences in the variability of the samples and in the specification of saleable yield. The first Irish trial is the only comparative trial to have been conducted (Allen and Finnerty, 2000). A sample of nearly 400 steer half carcasses were boned out and trimmed to a commercial specification. Roughly two thirds of these were used to calibrate the three systems and the rest (n = 139) were used for validation. There were only small differences between the three systems in their ability to predict saleable yield, with RSD's between 1.12 and 1.20%. Surprisingly though, the classification scores plus carcass weight were equally accurate (RSD = 1.21). This may have been due to the fact that a panel of three classifiers was used and the consensus scores were probably more reliable than those of individual classifiers as used in other trials. The fact that the specification did not involve heavy trimming of fat may also have been a factor. Primal yield was therefore calculated by excluding the trim and the flank. However, the VIA systems were less accurate than the classification scores and weight at predicting primal yield (RSD = 1.44 v 1.50 – 1.56).

Conclusions. VIA systems are able to predict EUROP conformation and fat cover scores with acceptable accuracy and are likely to be more consistent than classifiers. They can also predict saleable yield with an acceptable accuracy. In the longer term as the industry becomes familiar with the technology and confidence in it grows it is likely that they will be used to assess saleable yield and other parameters related to carcass value.

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Genetic effects on beef meat quality

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Introduction Besides slaughtering conditions and technological considerations, meat characteristics depend directly on the muscle biology of live animals, which is regulated by genetic, nutritional and biological factors. Among the latter, the genetic factors are of prime importance because genetic improvement is permanent and cumulative when inherited by the next generations. This paper aims to review the effect of genetic factors on different quality traits of beef (especially sensory quality and healthiness). The genetic factors can be demonstrated by comparing different breeds or different genotypes of the same breed through biochemical, QTL or genomic studies or by the determination of genetic markers which affect muscle biology. The muscle traits which are regulated by genetic factors are intramuscular fat content and composition (affecting flavour and healthiness), and the characteristics of connective tissue and muscle fibres (affecting basal toughness and meat tenderisation, respectively). However, these parameters are interlinked: the ageing speed of fast-glycolytic muscle fibres is known to be the highest, a factor which may favour tenderness, whereas the lower fat content is detrimental for flavour but nevertheless healthy (Geay *et al.,* 2001).

Breed effects on beef quality It is well known that different cattle breeds or genotypes differ in their muscle characteristics due to marked differences in animal physiology. Consequently, beef meat may differ in quality depending on the animal genotype. For instance, meat from *B. indicus* breeds is less tender than meat from *B. taurus* cattle, and the magnitude of the *B. indicus* effect varies with muscle. The lower tenderness is due to reduced proteolysis of myofibrillar proteins in muscles from *B. indicus,* associated with a higher activity of calcium-dependent protease inhibitor (Whipple *et al.,* 1990b). It was also demonstrated that beef breeds (Blonde d'Aquitaine and Limousin) were characterized by lower values for collagen content, compression and shear force in raw and cooked meat respectively, compared to dairy (Holstein) or dual purpose (Brown Swiss) breeds. Texture differences between animals and breeds decreased with ageing time (Monson *et al.,* 2004). Another study comparing two French rustic breeds (Aubrac, Salers) and two French beef breeds (Limousin, Charolais) did not detect any significant differences in eating quality. Slightly higher eating quality was, however, observed in Limousin and Aubrac. Differences in quality between breeds are often less than among animals within breeds and are overridden by larger differences between muscles or cuts (Dransfield *et al.,* 2003).

It is also well-known that late-maturing beef breeds (Belgian blue, Limousin and Blonde d'Aquitaine) deposit more muscles and less fat compared to dairy breeds or early-maturing beef breeds (Angus and Japanese Black cattle). Less intramuscular fat may be detrimental to flavour, especially in young animals such as young bulls which are slaughtered at 15-18 months of age. Breed differences reported in the literature are thus often confounded with differences in precocity, and hence fatness. As a result some authors have compared beef quality from steers of four different breeds (Angus, Simmental, Charolais and Limousin) with the same level of intramuscular fat. Under these conditions, Angus and Charolais provided pale meat with low haem iron content. Beef from Angus and Limousin was more tender. The flavour was similar among breeds while juiciness was the highest for Limousin and the lowest for Angus. The juiciest beef showed the highest drip losses and the lowest cooking losses (Chambaz *et al.,* 2003).

Another study was recently carried out on 243 young bulls from 8 different European beef breeds from Spain, Italy and France. The breeds with higher beef aptitude (e.g. Piemontese) had a lower pH of thawed meat after 10 days of ageing, while the more rustic breeds (e.g. Asturiana de la Montaña, Avileña) had higher pH, lower drip losses and, in terms of meat colour, lower lightness and yellowness but higher redness. The highest values of shear force were observed for the Spanish rustic breeds and the Charolais breed on raw meat, but for Marchigiana and Piemontese on cooked meat. Compression at 20% of maximum compression stress, which may be related to myofibrillar resistance, did not discriminate breeds unlike compression tests at 80% of maximum stress, which is associated with connective tissue resistance. The highest values were observed for the two Spanish rustic breeds and the Charolais breed, whereas the lowest value was observed for the Piemontese (Failla *et al.,* 2004). The two rustic breeds were also characterized by a more oxidative muscle metabolism and a higher proportion of fast oxido-glycolytic fibers (Jurie *et al.,* 2004). This clearly explains the differences in colour, and probably in pH and drip losses. However, the differences in toughness are less clear and more complicated to explain since more parameters related to fiber type, proteolysis rate during ageing and collagen characteristics are involved.

A key issue from a nutritional point of view is to increase the proportion of polyunsaturated fatty acids (PUFA) and of CLA (conjugated linoleic acid) in beef. The leanest breeds are characterized by a higher proportion of PUFA, and CLA content is proportional to intramuscular fat content. Japanese Black cattle are also genetically predisposed to producing lipids with higher mono-unsaturated concentrations. However, although significant, these differences are probably of little value from a nutritional point of view due to the low contribution of beef fat in the human diet (reviewed by De Smet *et al.,* 2004).

Monogenic inheritance of beef quality: the double-muscling character The Double Muscling phenotype (DM) is characterized by a generalised hypertrophy of muscles (+25%). Conversely, DM animals display reduction in the size of the other organs (-40%) and have less fat and bone. DM is also characterised by increased stress susceptibility, reduced fertility, calving difficulties (dystocia) preventing calving without assistance, and low calf viability (for a review, see Bellinge *et al.,* 2005). The overall increase in muscle mass, which is due to an increase in the number of muscle fibres (hyperplasia) and to a lesser extent to fibre enlargement (hypertrophy), differs among muscles. DM animals have a higher proportion of lean meat than normal cattle. Their meat is pale and tender, mainly due to an elevated proportion of white fast-twitch glycolytic fibres and a lower collagen content. Their meat has also reduced flavour due to a lower amount of intramuscular fat. DM cattle are also characterised by a different hormonal and metabolic status in the form of lower plasma concentrations of triiodothyronine, insulin and glucose (Hocquette *et al.,* 1999).

The DM phenotype is controlled by the *mh* (muscle hypertrophy) gene, mapped to the centromeric end of *B. taurus* chromosome (BTA) 2. Grobet *et al.* (1997) showed that the myostatin gene maps to the *mh* locus. Myostatin (GDF-8) knocked-out mice exhibit double-muscling. Myostatin is known to be a growth factor that inhibits myoblast proliferation and hence regulates muscle development and growth (see reviews from Kambadur *et al.,* 2004 and Bellinge *et al.,* 2005). Mutations disrupting myostatin lead to the DM phenotype in cattle and can be explained by a higher rate of myoblast proliferation. However, DM in European cattle breeds is characterised by allelic heterogeneity and a number of independent mutations were observed. Several loss-of-function mutations have been identified within the 3 exons of the coding region of myostatin (Grobet *et al.,* 1997). They include (i) either deletions such as the 11-bp deletion of nucleotides in exon 3 referred to nt821(del11) in Belgian Blue DM (Grobet *et al.,* 1997) or (ii) amino acid changes such as the C313Y mutation within exon 3 in Piedmontese and Gasconne breeds or the Q204X mutation in Charolais (for a review, see Kambadur *et al.,* 2004). The mutations result in the production of either an out-of-frame truncated or a full-length inactive myostatin protein. Interestingly, the Blonde d'Aquitaine cattle do not display any of these mutations but show similar characteristics to DM cattle (Listrat *et al.,* 2001).

The characteristics of DM muscles already appear during foetal development. This is not surprising since myostatin expression is detected from 16 days in bovine embryos (for a review, see Kambadur *et al.,* 2004) and is regulated throughout gestation (Deveaux *et al.,* 2003). At 100 days of foetal life, homozygote DM foetuses displayed enlarged muscles (Deveaux *et al.,* 2001) and an increased total number of muscle fibres. This is due to an increased proliferation of myoblasts as observed in primary cells cultured from DM foetuses (Picard *et al.,* 1998; Deveaux *et al.,* 2001). The higher proportion of fast-twitch glycolytic IIX fibres results from higher proliferation rates of the second generation of myoblasts (Deveaux *et al.,* 2001). Accordingly, myostatin expression was found to be located in the latest differentiating cells from the second generation (Deveaux *et al.,* 2003). In addition, muscle contractile and metabolic differentiation of DM foetuses is delayed compared to that of normal animals (Gagnière *et al.,* 1997) as DM muscles expressed fewer mature myosin heavy chains at the same gestational age during the first two-thirds of foetal life (Picard *et al.,* 1995).

DM cattle is thus a very interesting model to study the effects of one major gene in interaction with other genes, and to understand how an increased muscular mass may be associated with lower intramuscular fat and collagen contents.

Polygenic inheritance of beef quality Comprehensive research studies were initiated in the early 90's by the US Meat Animal Research Center, Nebraska, taking advantage of their extensive Germ Plasm Evaluation project. The systematic measurement of meat quality and beef production traits simultaneously provided the first estimates of genetic parameters on a large sample of animals. Complementary results have been obtained in different state Universities: Colorado, Texas, Louisiana, Florida (for a review, see Burrow *et al.* (2001); other studies were published by Kim *et al.* (1998) and Riley *et al.* (2003)). The animals were mainly steers intensively fattened in feed lots and slaughtered at 15 months of age on average. A large diversity of breeds was analysed, included *B. Indicus* crosses. Another set of novel results were obtained by Cooperative Research Center for the cattle and beef industry, conducted in Australia (Reverter *et al.,* 2000, 2003; Johnston *et al.,* 2003). Temperate and tropically adapted breeds were studied in different finishing conditions, feed lot or pasture, temperate or tropical regions. Steers and heifers were slaughtered at 20 to 30 months of age, due to a long growing period on pasture before fattening, especially in the tropical region.

The meat quality attributes were measured with taste panels scoring tenderness, juiciness and flavour of cooked meat. In these studies, steaks were grilled to an internal temperature of 70°C. Genetic variability was estimated in 10 different publications and average heritability coefficient is moderate for tenderness score ($h^2 = 0.24$) and low for juiciness and flavour scores ($h^2 = 0.11$ and 0.09 respectively). However, the genetic correlation coefficients between the three scores are very high ($r_g = 0.84$ to 0.91 on average) suggesting the panel could hardly be used to discriminate between the quality attributes. A larger number of studies included shear force, a mechanical measure of the texture of cooked (70 °C) meat, either grilled (US) or cooked in water bath (Australia). The published heritability coefficients average $h^2 = 0.26$ (n = 14) and the genetic correlations with tenderness score is very high too: $r_g = -0.84$ on average. Shear force appears therefore as an objective alternative for measuring and selecting meat tenderness.

However, other predictors of meat quality were sought for an indirect selection of meat quality genetic merit. Nine studies included the measurement of lipid content. It was shown that intramuscular fat has much higher genetic variability (h² = 0.49), and is favourably correlated to tenderness (r_g = 0.41, n = 4) or shear force (r_g = - 0.50, n =5) on average. As marbling scoring in these animals has high genetic correlation with lipid content (r_g = 0.91, n = 4), a selection on marbling score may provide for a correlated improvement of tenderness (r_g = 0.46, n = 7) or a decrease in toughness (r_g = - 0.50 with shear force, n =8). This relationship drives most of efforts dedicated to improving meat quality in the USA and Australia. Presently, research has been directed towards the development of life scanning of lipid contents as a selection tool (Hassen *et al.,* 2001; Reverter *et al.,* 2000; Sapp *et al.,* 2002). However, marbling is positively correlated to the carcass fatness (r_g = 0.36, n = 6, review of Koots *et al.,* 1994) and the indirect improvement of tenderness through a selection on intramuscular lipid content or marbling will have counterproductive effects on carcass quality.
As calpastatin, a major regulator of the calpain proteolytic activity during ageing, was shown to account for a significant proportion of variation in beef tenderness (Whipple *et al.,* 1990a), its activity was measured in four studies. There is a high genetic variability (h² = 0.44), and significant genetic correlations with tenderness (r_g = 0.61) and shear force (r_g = - 0.48) on average. However, this activity is not easy to measure and is unreliable for selection. Thus, research studies are directed towards seeking molecular polymorphisms in the calpastatin or calpain genes related to tenderness variability.

Few research studies have been conducted on the genetic variability of colour measurement (Aass, 1996; Johnston *et al.,* 2003). The parameters of lightness (L*) and redness (a*) are moderately heritable: h² = 0.22 and h² = 0.15 respectively.

In France, a study was conducted to estimate the predictive value of different muscle characteristics on the phenotypic variability of meat quality attributes of young Charolais bulls slaughtered at 17 months of age (Renand *et al.,* 2001). With this type of animals and a low cooking temperature (55 °C), it was shown that tenderness depends mainly on muscle fibre size and collagen characteristics and was poorly related to intramuscular lipid content. Genetic parameters of these muscle characteristics were estimated (Youssao *et al.,* 2004) to have moderate heritability coefficients (h² = 0.17 to 0.34). Genetic correlations with carcass traits were also estimated: a selection for leaner carcasses will decrease lipid and pigment contents, decrease the muscle fibre size and improve the collagen solubility. As a consequence, we may expect tenderness to be improved, but colour and flavour to be decreased. From a biochemical point of view, the genetic selection for muscle growth capacity induced a lower intramuscular fat content. It also induced a lower activity/expression level of some indicators of muscle oxidative metabolism (for instance mitochondrial enzymes) especially in oxidative muscles. This study showed however a muscle-specific response of metabolic characteristics to the selection process. Positive correlations between carcass fatness, muscle triglyceride content, and a marker of adipocyte differentiation (the expression of the *A-FABP* gene) have been shown among animals (Hocquette *et al.,* 2004).

Genetic markers of beef quality With regard to beef meat quality, information on genetic markers is still very limited. Indeed, genetic variability has been proved to be large enough for these traits and should enable genetic markers to be detected and then used to increase beef quality through marker-assisted selection (MAS). During the past ten years, large efforts have been engaged to detect QTLs, especially in the USA or in Canada and several studies on beef quality have also been performed in Australia, Europe and Japan. These studies were recently reviewed (Kühn *et al.,* 2005) and were mainly focused on tenderness and on the amount and the composition of intramuscular fat. Several of them have investigated meat quality in *B. taurus* x *B. indicus* crosses, where a very large difference in meat quality traits, particularly toughness, is known.

Tenderness. Several studies independently identified a QTL on BTA29 with effect on tenderness, either in crosses between *B. taurus* and *B. indicus* or in crosses between *B. taurus* breeds (Casas *et al.,* 2005 ; Schmutz *et al.,* 2000 ; see review by Kühn *et al.,* 2005). Page *et al.* (2002) suggested that genetic variants of the *CAPN1* (calpain 1) gene, which is located in the same chromosomal region, are the functional background of this QTL, because 2 SNPs in exons 9 and 14 were associated with variations in tenderness measured by a shear force test on *Longissimus dorsi*. It should be noted that these 2 polymorphisms correspond to amino-acid substitutions (A316G and I530V) and that three combinations (alleles or haplotypes) have been described. Other QTL with impact on beef tenderness traits were identified on BTA4, 5, 9, 11, 15, and 20, but have not been confirmed in independent studies nor is there evidence for a gene within the QTL region that could be considered as a strong candidate. On the contrary, polymorphisms in two genes, *CAST* (calpastatin) and *LOX* (Lysyl oxidase), both located on BTA7, where no QTL for tenderness has been reported, have been associated with an effect on the beef tenderness trait (Barendse, 2002a). For *CAST*, 2 SNPs located in the 3'UTR region and a microsatellite located in the 5' region were reported: only 2 haplotypes have been shown to be associated with improved tenderness and it was suggested that the known markers are in linkage disequilibrium with a causative mutation that has not yet been identified.

Marbling. As reviewed by Kühn *et al.* (2005), several QTLs for marbling were reported and located on BTA2, BTA3 and BTA27. Interestingly, the myostatin gene lies on BTA2 where the QTL was detected (Casas *et al.,* 1998). However, it seems unlikely that this gene is involved in the variation seen in all studies because some did not include breeds known to be carriers of double muscling. Other QTLs on BTA5, 8, 9, 10, 14, 16, 17, 23, and 29 were also reported but have not yet been confirmed. In contrast to the multitude of studies investigating the amount of intramuscular fat, there is only one report describing loci with impact on the composition of the intramuscular fat (Taylor *et al.,* 1998), but the study was restricted to the investigation of a single chromosome (BTA19) and to the comparison of *B. taurus* and *B. indicus* alleles. Genetic markers associated with intramuscular fat deposition or marbling were reported, and are located on two chromosomes, BTA5 and BTA14, where QTL for these traits were suggested elsewhere. On BTA5, the polymorphic microsatellite loci CSSM34 and ETH10, which are 20 cM apart, are associated with marbling scores in the Angus, Shorthorn, and Wagyu breeds (Barendse, 2002b). The *DGAT1* (diacylglycerol-O-acyltransferase) and the *TG* (thyroglobulin) genes are both located in the centromeric region of BTA14. An Ala232Lys polymorphism of the *DGAT1* gene has been shown to have an effect on intramuscular fat deposition in German Holstein and Charolais (Thaller *et al.,* 2003) and an association between one *TG* haplotype, based on 2 SNPs, and marbling has been reported (Barendse, 2002b). No association between both markers and carcass composition was found however in *B. indicus* cattle by Casas *et al.* (2005). It seems the markers have independent effects, because no statistically significant linkage disequilibrium was detected. Several SNPs in the *LEP* (leptin) gene have been described, and two of them located in exon 2 were reported to affect fat content or feed intake in independent studies (Buchanan *et al.,* 2002; Lagonigro *et al.,* 2003). The fatty acid composition of beef has an impact on the softness of the fat and also on flavour. In Wagyu cattle, Taniguchi *et al.* (2004) identified an association between a polymorphism in the *SCD* (stearoyl-CoA desaturase) gene and the mono-unsaturated fatty acids (MUFA) content as well as the melting point of intramuscular fat.

SNP identification. Other efforts are devoted to the identification of SNPs in a large set of candidate genes with a view to evaluating their association with meat quality data measured across a wide range of genetically divergent breeds. Within the context of an EU-funded project (GeMQual, www.gemqual.org), a list of about 500 candidate genes that may be expected to have an influence on muscle development, composition, metabolism or meat ageing and hence affect the quality of meat, has been established from knowledge of their physiological role. Coding and non-coding regions from about 400 of these candidates have been sequenced to reveal polymorphisms (Levéziel *et al.,* 2003). So far, a total of about 710 SNPs has been identified in 209 genes and these SNPs are being genotyped in 450 bulls that have been measured for meat characteristics in the project. The expected results should provide indication of genes that may have an effect on the meat quality traits and that will be targets for further studies.

The potential benefits of genomics Scientists used to study one gene at a time in isolation from the larger context of other genes. Nowadays, they have access to gene networks and interaction thanks to the development of transcriptomics and proteomics which allow the high-throughput detection of genes which are differentially expressed between breeds and genotypes. A great number of studies dealing with functional genomics in cattle have been published so far (reviewed by Hocquette *et al.,* 2005). All those related to the genetic effects on beef meat quality will be reported here.

Differentially expressed sequence tags were isolated in the liver and in the intestine between cows of different metabolic type (Dorroch *et al.,* 2001). Wang *et al.* (1995) have shown that the genes which are more expressed in muscles from Japanese Black cattle (which produce marbled beef) compared to Holstein are associated with unsaturated fatty acid synthesis, fat deposition, and the thyroid hormone pathway. Potts *et al.* (2003) have compared gene expression in DM and normal bovine 31-33 day-old embryos by using suppressive subtractive hybridisation. They have identified genes encoding transcription factors, modulators of protein synthesis and degradation, proliferation or metabolism, and three of the differentially-expressed genes were physically mapped to BTA5, very close to the Warner Bratzler shear force at day 14 *post-mortem* interacting QTL peak. The orientation towards fast glycolytic type muscles from DM cattle was confirmed by Bouley *et al.* (2005) who compared the proteome of *Semitendinosus* muscle of DM and normal animals. In this muscle, the expression of proteins was affected including proteins belonging to other pathways than contraction and metabolism or with unknown function such as sarcosin, SR53G, and heat shock protein p20.

With regard to the model of polygenetic inheritance of muscle growth potential, a recent study has compared gene expression in muscles from Charolais bulls divergently selected for muscle growth. Besides known genes (encoding mitochondrial enzymes and *A-FABP*), other novel genes such as *LEU5* (a tumor suppressor), sarcosin (a muscle-specific gene involved in human hypertrophic cardiomyopathy) and a heat shock protein have been demonstrated to be less expressed in muscles from animals with a high muscle growth potential (Sudre *et al.,* 2005). Some of these genes were also previously detected as differentially expressed throughout muscle development (Sudre *et al.,* 2003). In addition, other recent transcriptomic studies confirmed that a selection in favour of a higher muscle growth potential induces a higher expression of genes involved in glycolytic (e.g. lactate dehydrogenase A) or fast muscle traits (e.g. tropomyosin beta and myosin heavy chain 2x) (Cassar-Malek *et al.,* 2005). As for DM cattle (Bouley *et al.,* 2005), proteomic studies have also demonstrated the under-expression of slow troponin T isoforms and the over-expression of fast troponin T isoforms as well as of other proteins abundantly expressed in fast glycolytic muscles (Picard *et al.,* 2005).

As described above, functional genomics is nowadays providing catalogues of muscle genes regulated by various factors, but sometimes without any real information about gene function. A reasonable approach is thus to consider a microarray experiment as exploratory data analysis, with a view to identifying potentially interesting genes which remain to be further studied. We must however keep in mind that gene expression differs a lot between muscle types (Cassar-Malek *et al.,* 2005). This may be due, among other factors, to the fact that the muscle tissue is a complex mixture of cell types (including myofibers, connective tissue fibroblasts and adipocytes) which differ in their proportions between muscles. So, we do not know which cell population is responsible for the observed changes. A second problem is that genomics simply score mRNA or protein levels. In fact, it is quite difficult to identify the causal genes also called master controllers (which regulate the expression of groups of genes). Unfortunately, because transcription factors and cell regulators are often expressed at low levels, they can not be detected easily by genomic approaches. A final problem is that arrays do not have universal genome coverage in cattle, which is a major limit to discovering new genes. Besides these limitations, genomics may help to identify genes, especially those which show significant changes in expression over environments, suggesting that their expression level depends mainly on genetic factors. Furthermore, the tremendous progress in animal models (from yeast to laboratory rodents) will help in identifying master controllers. This is comparative genomics. So, genomics is currently changing the face of biology. A cost-benefit analysis should be, however, seriously considered before any practical application (Walsh and Henderson, 2004).

Conclusion Genetic selection in some countries (for instance France and Belgium) was directed in favour of high muscle development and low fat development to produce leaner meat. This has been indeed successful in increasing growth rates of beef cattle. However, this type of genetic selection has clearly induced an orientation towards the fast-glycolytic muscle type as has recently been shown by biochemical, transcriptomic and proteomic approaches in both double-muscled cattle and divergently selected Charolais bulls. This is important because, nowadays, consumers seek meat of high and consistent quality and the concept of quality includes now not only eating quality but also nutritional value, healthiness and any other consideration important for consumers. In this context, the orientation of the muscle type towards the fast-glycolytic type may favour tenderness and healthiness but is detrimental for flavour due a reduction in intramuscular fat content. In addition, the increasing knowledge in muscle biochemistry has shown that breeds differ in connective tissue and fibre characteristics with potential consequences on both tenderness and flavour.
The advent of genomics will undoubtedly increase our knowledge of the genes involved in determining beef quality. The major outcomes are (i) the development of DNA tests to improve beef quality by genetic selection, and (ii) the identification of molecular markers to predict the ability of animals to produce beef with desirable quality traits for the consumers. It is however important to underline that most, if not all, of the studies published so far need to be confirmed and enlarged before the markers reported are used in practice, because the associations have been observed in a limited number of breeds and breeding systems (Renand *et al.,* 2003). Undoubtedly, further progress will be made in the future when the entire bovine genome sequence becomes available and SNP markers at high density are identified. Future efforts will have to be made to collect phenotypic data on large numbers of animals, especially for traits which are not currently measured routinely. Then, as the availability of SNP markers increases, the genotyping costs decrease and the functional genomics develops, there will be clear evidence of useful molecular markers.

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Biological bases that determine beef tenderness

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Introduction Our research objectives of the last 20 years have been to determine the biological mechanisms that regulate beef tenderness and to use this information to develop technologies to enable beef producers and processors to provide consumers with satisfying eating experiences.

U.S. consumers consider tenderness to be the single most important component of meat quality. This fact is easily confirmed by the positive relationship between the price of a cut of meat and its relative tenderness (Savell and Shackelford, 1992). Inconsistency in meat tenderness has been identified as one of the major problems facing the U.S. beef industry. We recognize that palatability has several components, which include tenderness, juiciness, and flavor. It is a combination of these eating attributes that determines the degree of eating satisfaction. However, we have concentrated our research efforts at the U.S. Meat Animal Research Center (MARC) on understanding the biological bases that regulate beef tenderness (for review see Koohmaraie, 1995). The reason for focusing on tenderness is that, under current production practices in the United States, there is twice as much variation in tenderness as in juiciness and flavor and because consumers consistently identify tenderness as the most important factor. Therefore, the problem of consumer dissatisfaction will be solved if we solve the problem of tenderness variability.

The sources of longissimus tenderness variation Variation in meat tenderness exists at slaughter, is created during postmortem storage, or is a combination of both. Certainly, meat preparation by consumers also can be a source of inadequate meat tenderness. However, food preparation is not a researchable problem and is not a focus of this presentation. Food preparation is a problem that can and should be addressed through consumer education. In an attempt to determine the source(s) of variation in meat tenderness, we conducted an experiment that demonstrated that on average lamb longissimus has an intermediate Warner-Bratzler shear force value immediately after slaughter (5.07 kg), toughens during the first 24 hours after slaughter (maximum toughness was achieved at 9 to 24 hours; 8.66 kg), and then becomes tender during postmortem storage at 4°C (3.10 kg). Rigor-induced meat toughness is caused by sarcomere shortening that accompanies the development of rigor mortis (Wheeler and Koohmaraie, 1994). We refer to rigor-induced toughness as the toughening phase. Sometime after death an opposing process called tenderization begins and will continue for some time postmortem. There is more variation among animals in the tenderization phase than in the toughening phase. In fact, it is well documented that there is a large variation in the rate and extent of postmortem tenderization in the longissimus (for review see Koohmaraie, 1992a,b; Koohmaraie, 1995, 1996). It is a combination of this variability in the tenderization process and variability in the amount of aging time allowed before sale of the meat that results in much of the inconsistency in meat tenderness at the consumer level. To solve this problem, we must identify the reasons for the variability in the rate and extent of postmortem tenderization so that the tenderization process can be manipulated to accelerate and equalize it between carcasses and/or develop the necessary technology to identify those carcasses that will not respond to postmortem tenderization. Without this information, we will continue to have inconsistency in meat tenderness at the consumer level.

Postmortem tenderization is caused by degradation of proteins that are involved in scaffolding of the muscle structure. Once these proteins are degraded, the muscle is weakened. Weakening of the muscle results in reduction of muscle resistance to chewing, that is, tenderization. These proteins are degraded by an endogenous enzyme system called the calpain proteolytic system. The calpain system has three components: a low-calcium-requiring enzyme (μ-calpain), a high-calcium-requiring enzyme (m-calpain), and an inhibitor, (calpastatin), which specifically inhibit the activity of the calpains. Calpains have an absolute dependency on calcium for activity. Although most beef responds to postmortem storage (i.e., by tenderization), the rate and extent of tenderization varies such that some beef does not benefit from extended postmortem storage. Postmortem tenderization occurs fastest in pork followed by lamb and then beef. To improve the consistency of meat tenderness, beef, lamb, and pork should be aged at least 14, 10, and 5 days, respectively. This practice alone will eliminate a large portion of the observed variation in meat tenderness. Tenderization occurs at the same rate for vacuum packaged subprimals as for dry-aged cuts of meat. Also it is important to recognize that tenderization occurs regardless of the size of the cut of meat (carcass, primal cuts, steaks, roasts, etc.) and that tenderization will occur faster at higher temperatures, but does not occur at all in frozen meat.

Genetics Many scientists and producers have suggested that controlling the genetics of the slaughter cattle population would entirely solve the beef industry's tenderness problem. We agree that genetics make a large contribution to the total variation in tenderness. However, genetic analyses indicate that environmental factors make a much larger contribution to variation in tenderness. Thus, it may be more efficient to improve tenderness through management and processing procedures than genetic selection.

On average, some breeds of cattle produce more tender meat and some produce less tender meat relative to other breeds (Koch *et al*., 1976, 1979, 1982b; Wheeler *et al*., 1996, 2001, 2004, 2005). It is well documented that the mean shear force and variation in shear force increases as the percentage of *Bos indicus* inheritance increases (Crouse *et al*., 1989).

Furthermore, meat from one-half or greater *Bos indicus* (Brahman, Nellore, Sahiwal) cattle is usually significantly less tender than meat from cattle with less than one-half *Bos indicus.* However, we have identified heat-tolerant germplasm (the Tuli breed) that does not have decreased meat tenderness (Wheeler *et al*., 2001). On the other hand, several breeds (Jersey, Pinzgauer, South Devon, Red Poll and Piedmontese) tend to produce meat that is more tender than meat from other breeds. On average, most breeds are fairly similar in meat tenderness. However, there is more variation within each breed than among the most different breeds. The amount of change that could be expected in shear force by selecting Pinzgauer instead of Nellore purebred cattle is 4.76 genetic standard deviations, while the within-breed variation is 6 genetic standard deviations. For F1 progeny this same comparison results in 2.38 genetic standard deviations between Pinzgauer- and Nellore-sired progeny, although only 1.43 phenotypic standard deviations are realized among Pinzgauer- and Nellore-sired progeny. Thus, the realized improvement in tenderness from selecting one breed over another will be small (at most 1.43 kg of shear force; to change from half-blood Nellore to half-blood Pinzgauer). To make additional improvement within a breed requires identifying those sires (and dams) whose progeny produce more tender meat, either through progeny testing or some direct measure on the sire and dam to predict the tenderness of their progeny.

Traditional animal breeding theory indicates that the most effective genetic selection is made through progeny testing. Due to the time required, progeny testing may not be a practical method by which to improve tenderness. If we make the following assumptions: use of 13 sires, inbreeding held to less than 1%, 100 head cow herd size, heritability estimates of 0.30 for shear force and 0.42 for marbling, the genetic correlation 0.25 between shear force and marbling (Koch *et al*., 1982a, and the references therein), and standard deviation of 1.0 kg for shear force, then it would take 12.0 years and 40.7 years to improve shear force by 1.0 kg by selection for shear force or marbling, respectively. If we increase the size of the cow herd to 500, the above estimates will be 6.8 and 23.1 years, respectively. Obviously, a significant change in the above parameters will affect these estimates. Data collected at the U.S. Meat Animal Research Center indicate that extreme culling would have to be imposed to eliminate all tenderness problems through genetics. The rate of genetic improvement in a given trait is a function of the heritability of the trait, the generation interval, and the selection differential. MARC data indicate that the maximum selection differential that could be imposed for tenderness is relatively small. In fact, the distributions of shear force values overlap for the progeny of the toughest and most tender ten percent of sires. Moreover, if we culled the toughest 10% of sires we would only decrease the frequency of shear values above 4 kg from 20% to 16%. Thus, extreme culling would have to be imposed to eliminate all tenderness problems through genetics. Undoubtedly it would be impossible to select heavily for tenderness without compromising other economically important traits. It appears to us that the beef industry should (1) exploit breed complimentary and heterosis through crossbreeding to balance production, carcass, and meat traits and (2) use appropriate production, processing, and evaluation procedures to guarantee tenderness. This should not be interpreted to mean that the genetic contribution to tenderness is not important. The major impact that genetics can have on meat tenderness is well documented.

Methods of predicting beef tenderness The amount of money a processor can spend on identifying "guaranteed tender" product depends on several factors, such as the amount of premium that product will generate, the proportion of carcasses that will qualify, potential reduction in value of non-qualifying product, and the weight of product (number of cuts) from each carcass that can be marketed as enhanced in tenderness. The method selected to identify "guaranteed tender" must be accurate enough to create a product that is recognizable by consumers as superior in tenderness. Furthermore, it would seem likely that tenderness certification would be applied to USDA Select and Low Choice carcasses because USDA Prime carcasses and most of the carcasses within the upper two-thirds of Choice already receive premiums in the market. Thus, USDA Select and Low Choice carcasses would be logical candidates for increased value by identifying those that are "tender."

There have been many attempts to identify instrumental methods for predicting meat tenderness (reviewed by: Pearson, 1963; Szczesniak and Torgeson, 1965). Most of these were intended for laboratory research tools and varied widely in their efficacies. In more recent investigations of objective predictions of meat tenderness, the goal has been to develop on-line systems for grading carcasses based on tenderness. The ideal system would involve an objective, non-invasive, tamper-proof, accurate, and robust technology. Technologies evaluated for their potential as on-line tenderness grading tools include Tendertec (George *et al*., 1997; Belk *et al*., 2001), connective tissue probe (Swatland, 1995; Swatland and Findlay, 1997; Swatland *et al*., 1998), elastography (Berg *et al*., 1999), near-infrared spectroscopy (Hildrum *et al*., 1994; Park *et al*., 1998, Shackelford *et al*., 2004, 2005), ultrasound (Park and Whittaker, 1991; Park *et al*., 1994), image analysis (Li *et al*., 1999, 2001), colorimeter (Wulf *et al*., 1997; Wulf and Page, 2000), BeefCam (Belk *et al*., 2000), and slice shear force (Shackelford *et al*., 1999a,b, 2001). A majority of these have been shown to lack sufficient accuracy in predicting meat tenderness to be useful. The three that appeared to be most promising (BeefCam, Colorimeter, and Slice Shear Force) were recently compared directly in the same study (Wheeler *et al*., 2002).

The National Cattlemen's Beef Association (NCBA) recently convened a committee on the National Beef Instrument Assessment Plan II–Tenderness (NCBA, 2002). This committee evaluated currently available technology and concluded that the only technology accurate enough to be used was slice shear force. The committee recommended that the industry proceed with implementing this technology and collect baseline data to determine the level of variation in tenderness that really exists so that sources of this variability can be identified and approaches developed to improve consistency. The committee also recommended that development efforts continue for non-invasive technologies.

Methods of improving meat tenderness There are a number of ways to improve meat tenderness. We have listed in order of their relative importance (in our opinion) some approaches for increasing meat tenderness. (1) The easiest one to apply is to ensure a minimum amount of "aging" time. Storing meat at 0° to 3°C (aging) for an extended period of time allows for tenderization due to μ-calpain degradation of key structural protein. A minimum of 5 (pork), 10 (lamb), and 14 (beef) days of aging will ensure a majority of the carcasses will be relatively tender. (2) Proper application of high-voltage electrical stimulation will result in improved meat tenderness. The mechanism of electrical stimulation is thought to be primarily from structural damage to the tissue due to severe contractions. Although electrical stimulation has significant effects on the activities of the calpain system, it is not clear what net effect electrical stimulation has on postmortem proteolysis. (3) Sort carcasses based on longissimus tenderness at the time of grading. This information will enable the processor to identify carcasses with meat that is already tender and thus, after aging can be guaranteed tender for a premium product line. It will identify the meat that is borderline on tenderness that must receive the recommended minimum amount of aging time and it will identify the meat that needs a tenderness intervention process (e.g., marination, blade tenderization, etc.) to improve its tenderness (and it prevents the processor from wasting money applying tenderness interventions on meat that does not need it). (4) A few breeds are more tender on average, so a small improvement can be obtained in average tenderness by selecting these breeds over the others. (5) Some research indicates that aggressive implant strategies (over-implanting or too much trenbolone acetate) can reduce meat tenderness, so these should be avoided. (6) Stress on animals should be minimized within one week of harvest date to reduce "dark-cutters." Slight to moderate dark-cutting meat is frequently less tender, although extreme dark-cutting meat is sometimes exceptionally tender, but usually has strong off-flavors. (7) Intramuscular injections have been demonstrated to result in a region of decreased tenderness in the meat surrounding the injection site. Injections should be subcutaneous or, if they must be intramuscular, limited to less valuable areas such as the neck region. (8) Animals with chronic health problems such as respiratory illnesses may have reduced meat tenderness and should be removed from premium product lines. (9) A considerable amount of research indicates that cattle should be fed a high-energy grain diet for a minimum of 75 days before harvest. (10) In cattle, castration of males should be performed before 7 months of age to avoid reducing meat tenderness. (11) Age at harvest should be less than 30 months for cattle. These strategies should ensure that most beef is acceptably tender; by sorting for tenderness, those carcasses that are tough can be treated with one or more of the following tenderness interventions.

Marination Based on our knowledge of the mechanism of postmortem tenderization, we have developed a process that ensures meat tenderness (for review, see Koohmaraie *et al*., 1993; Wheeler *et al*., 1994). Calpains require calcium for activity. But, conditions in postmortem muscle are not always optimum for calcium to be available to activate calpains. Exogenous calcium can be added to meat, thus activating calpains and inducing more rapid and extensive tenderization. The process, known as calcium-activated tenderization (CAT), consists of injecting cuts of meat (either prerigor or postrigor) with 5% (by weight) of a 2.2% solution of food-grade calcium chloride. Following injection, cuts are vacuum-packaged and stored for seven days prior to consumption. For best results, commercial automatic pickle injectors should be used to ensure uniform distribution of the calcium chloride throughout the cut of meat. If at all possible, one should avoid use of hand held injectors. The process is more effective in prerigor (the first 3 hours after slaughter) meat, but can be used up to 14 days postmortem. It will not affect meat that is already tender, thus it will not make tender meat "mushy." At the recommended levels of calcium chloride, the process has little effect on other meat quality traits. The process is effective in all cuts of meat regardless of species, breed, or sex-class. The process is also effective in cuts of meat expected to be unusually tough. These include meat from sheep and cattle fed ß-agonist, old cows, *Bos indicus* cattle, and round muscles from bulls. CAT has been tested under commercial conditions in a large beef processing facility.

Marination is frequently used with phosphates, salt, and other seasonings. With marination that does not include calcium, the tenderizing effect is obtained by increased water binding and the halo effect from improved juiciness.

Blade tenderization It has long been known that blade or needle tenderization could be used to improve the tenderness of meat. The physical disruption of the tissue from numerous penetrating needles results in improved tenderness. Most meat destined for foodservice outlets, particularly higher quality restaurants, is treated with this process.

Conclusions Undoubtedly variation in tenderness of aged-beef at the consumer level must be controlled to improve customer satisfaction with beef. It has been shown that consumers are willing to pay more for beef of higher or guaranteed tenderness. Several processes can be implemented immediately to reduce this variation, while others require further research.

Over the years, numerous factors have been reported to affect tenderness of aged beef. We must sort through those factors and determine which ones are most relevant. Those factors determined to be of most importance for controlling variation in meat tenderness should then be established as critical control points. Critical control points would likely include some or all of the following: genetics, male sex-condition, age, time-on-feed, type of ration, implant protocol, preslaughter handling procedures, slaughter/dressing, electrical stimulation, chilling, postmortem tenderization technologies (calcium chloride-injection, blade tenderization, etc.), and aging.

In addition, our data suggest that even if all critical points are controlled, we will still have tough beef. Within all breeds there are animals that will not produce tender meat even when the best processing procedures are followed. This means that we must develop methodology to identify such animals. Currently, the method of choice is Slice Shear Force conducted at the time of normal grading (1 to 5 days postmortem). This approach can be used to segregate carcasses into aged beef tenderness groups with great accuracy. Because this method is invasive and results in devaluation of one top loin steak per carcass, the industry would like to have a method as accurate as Slice Shear Force, but not invasive. After years of research, we have developed a non-invasive method which appears to accurately identify carcasses that will be tender after 14 days of storage. We are currently field testing our new method in some U.S. beef processing plants.

Genome mapping and other projects to identity markers associated with tenderness of aged beef are progressing, but not as quickly as we had hoped. Once these markers are identified they could be used to: (1) select for tenderness, (2) sort feeder cattle to optimize quality and yield, and (3) predict tenderness. However, markers may only be useful within the family in which they were generated. By sequencing the location of these markers in the cattle genome the identity of the gene(s) affecting beef tenderness will be determined. It is only at this level of knowledge that we truly can maximize genetic effects on beef tenderness. One never knows what the future holds. Maybe the identity of these genes will allow us to sort cattle into expected tenderness groups prior to slaughter. When knowledge of genetics is combined with critical control of environmental sources of variation in tenderness we should be able to consistently produce tender beef.

Readers can find additional information at: http://meats.marc.usda.gov.

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Studies on beef eating quality in Northern Ireland

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Introduction

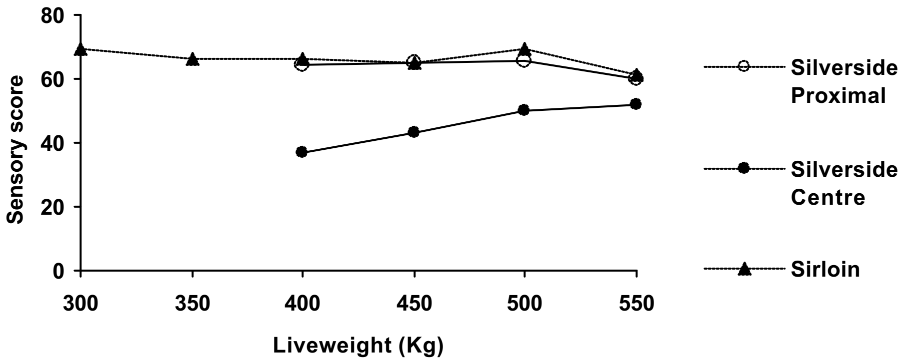
When a consumer eats meat they experience various attributes, which together make up 'eating quality'. These include texture attributes, such as tenderness and toughness, as well as juiciness, flavour and appearance. If these eating quality attributes match or exceed expectations, the consumer will be happy. If they are poorer than expected, the consumer will be disappointed and may be reluctant to purchase beef again. Clearly, it is in the interests of the beef industry that their consumers are generally happy with the eating quality of the beef they purchase.

In common with others (reviewed, for example, by Fergusson *et al*., 2001, Maltin 2003), DARD Science Service and ARINI in Northern Ireland have conducted studies on beef and other species from production and processing through to measurement of quality, using either sensory panels or instrumental methods. Some factors have a clear effect on eating quality while others give apparently sporadic effects. It can be difficult to determine whether production factors, such as breed or diet, influence eating quality directly or indirectly via their effect on fat cover and chilling rate. In this paper, studies will be highlighted that illustrate how interactions between these many different factors can have unexpected or complex effects on eating quality. In addition, recent research will be described that shows how consumers are changing in their expectations of eating quality. Finally, the direction of current research that combines both these approaches to predict and deliver the required eating quality will be briefly explained.

Northern Ireland studies on factors affecting eating quality

Effect of weight of young bulls. In Northern Ireland, approximately 50% of animals slaughtered for beef derive from the dairy herd while nearly 20% of animals are entire bulls. Such animals receive low EUROP grades for conformation and provide poor remuneration to the farmer. The meat is usually destined for the commodity minced beef market. Studies conducted using light-weight young bulls (Farmer *et al.,* 2004, Moss *et al.,* 2005) have shown that young bulls of only 300-550kg live weight can give good quality meat. Sensory studies demonstrated that, for both sirloin and the proximal portion of the silverside, there was no direct linear effect on eating quality by live weight on 21d-aged meat. Surprisingly, however, an interaction between live-weight and position in muscle showed that the centre portion of the silverside showed increasing quality for the larger animals (Farmer *et al.,* 2004; Moss *et al.,* 2005). There appears to be a relationship, which cannot be readily explained by fat cover, that causes the eating quality of different regions of the silverside to be affected differently by the weight of the animal (Figure 1).

Figure 1. Effect of live-weight and muscle type on the mean sensory scores for acceptability of texture of roast silverside (central portions), and also sirloin (separate experiment), from young bulls



Effect of breed. An interaction between breed and post-slaughter processing was observed in a study on the production, carcase and meat quality of purebred Charolais and Holstein steers (Lively 2005). The steers were slaughtered over a range of weights to allow regression equations to be established to predict parameters measured at specific carcase weights of the two breeds. When adjusted for age at slaughter and carcase weight, the *longissimus dorsi* of the Charolais had significantly greater cooking loss and Warner-Bratzler shear force values than the Holsteins. As expected, tenderstretch-hanging decreased Warner-Bratzler shear force values in both breeds. However, this decrease in shear force values due to tenderstretch was greater in the sirloins from Charolais than Holstein animals. Thus, processing under optimum post-slaughter management, such as the MLC Blueprint, may reduce the possible differences in tenderness between breeds. For example, Hilton et al., (2004) found no significant differences in eating quality between various English, Brahman, Exotic crosses "slaughtered according to normal, industry-accepted procedures". However, they did report a further interaction, that degree of doneness affected tenderness scores and that end-point temperature varied across phenotypes.

The effect of dairy breed type (Norwegian Red, Holstein and reciprocal crosses) and concentrate management was studied in relation to meat quality (Lively *et al.,* 2004). One of the interesting interactions in this study was that when the Warner-Bratzler shear force values in the sirloin were measured 7 days post-slaughter there were no differences due to either breed type or concentrate management. However, after 21 days aging the Warner-Bratzler shear force values were lower in the reciprocal crosses than in the pure breeds. This illustrates an important point that differences in production may depend on ageing period and post -slaughter management.

Effect of welfare and stress. It is well established that, for cattle, long-term stress leads to high pH meat, which is dark in appearance. This stress can be caused by mixing of strange animals prior to slaughter, resulting in aggressive behaviour, stress and glycogen depletion. Some years ago it was shown, in a study where different male types (bulls, vasectomised bulls, immunised bulls and steers) were mixed 18 hours prior to slaughter, that a strong positive correlation was found between the number of mounts performed by an animal, its sex type, and the ultimate pH of the *longissimus dorsi* (Mohan Raj *et al 1992*). There is now a well-known interaction between an animal's sex type, its aggressive behaviour, excitability and susceptibility to stress. High pH meat and DFD is generally more prevalent amongst bulls than in steers and heifers.

Effect of low voltage electrical stimulation on red meat quality

There has been considerable interest since the early 1970's in the commercial application of electrical stimulation within the meat processing industry, primarily as a means for overcoming cold-shortening. Gault *et al* (2000) clearly demonstrated that it was possible to induce a very rapid pH fall and early rigor onset in poultry carcases by low voltage electrical stimulation, without adversely affecting tenderness. This work, suggesting that heat shortening on the carcase is not a problem, has since been extended to assess the response of mixed fibre-type muscles in red meat species, using lamb as the experimental model. As shown in Table 1, the glycolytic responsiveness of different muscles, as assessed by pH measurement one hour after slaughter, is determined primarily by muscle fibre type balance ($P<0.001$), with most effect observed for the predominantly high-glycolytic α-white fibre-type muscles such as the M. *semitendinosus.* The M. *longissimus dorsi* (predominantly α-red) shows an intermediate response, while the highly oxidative M. *supraspinatus* (predominantly β-red) shows the least response. In addition, a clear statistical interaction ($P<0.001$) for $pH_{1.0h}$ was found between muscle type and frequency of low voltage electrical stimulation, highlighting the complex nature of the response to such stimulation, when considered in the whole animal context. Table 1 also shows that, although there are clear differences between muscles in shear force values ($P<0.001$), the appropriate use of low voltage electrical stimulation had little adverse effect ($P>0.05$) on this eating quality parameter, hot shortening prior to de-boning being avoided. The implications of this work for beef processing are clearly worthy of further investigation.

Table 1: pH decline in lamb carcases subject to low voltage electrical stimulation

Muscle	Control $pH_{1.0h}$	ES [a] $pH_{1.0h}$	Control pH_{24h}	ES pH_{24h}	Control SF [b] ($kgcm^{-2}$)	ES SF ($kgcm^{-2}$)
M. *longissimus dorsi*	6.5	6.2	5.6	5.6	4.7	4.8
M. *semitendinosus*	6.5	6.0	5.6	5.7	8.3	7.0
M. *supraspinatus*	6.7	6.4	5.8	5.8	6.0	6.4

a ES = electrical stimulation: 100V, 5Hz DC, 10ms pulse width, 1200 pulses over 4 min; n = 4 for each treatment;
b SF = Warner Bratzler shear force

These studies and many others illustrate the difficulty of predicting the effect on eating quality of any one factor, whether it be breed, sex, electrical stimulation or other factors.

Studies on Northern Ireland's consumers

The above studies are concerned with the effect of a range of factors on the eating quality of beef and other species. Also of interest are the factors that affect consumers' perception of beef (Egan *et al*., 2001; Resurreccion, 2004). It is frequently commented that beef consumption is declining, that people do not know how to cook it any more, that people are eating more ready meals, fast food or in restaurants. This paper reports selected results from two studies on the attitudes to beef amongst consumers. The first was a survey of 176 purchasers of beef, which was conducted in a range of supermarkets and several times of day. Purchasers were asked questions about the beef they had just selected, their consumption the previous week and their satisfaction with the beef they buy. The sample, although small, is representative of the socio-economic range in Northern Ireland as a whole. The second was conducted via a questionnaire completed by more than 1000 consumers (who regularly eat beef) contributing to taste panels. Prior to conduct of each sensory panel, consumers completed a simple questionnaire that asked to what level of 'doneness' they liked their steak cooked and how frequently they ate beef. This information can be linked to the sensory data from these consumers. Both surveys also asked socio-economic questions. Here we report one aspect of the results, the effect of a person's age on purchaser or consumer perceptions.

Effect of age on beef consumption. Frequency of consumption is lower in younger consumers of beef (Figure 2). Indeed, nearly 40% of the 15-29 year olds ate beef weekly or less frequently, while only 20% of consumers of 45 and older fell into this category. Similar results were obtained for 176 purchasers of beef. When asked how frequently they had eaten beef the previous week, 40% of those aged 60 and over had eaten it twice or less while more than 60% of those aged under 34 fell into this category. These trends will cause concern to the beef industry and the following data illustrate some of the reasons why younger consumers have changing purchasing patterns.

Effect of age on consumer choices. As might be expected, a person's age also affects the type of meat purchased and how it will be cooked (Figure 3). Whilst mince, sirloin and fillet steak and frying steak are purchased by all ages, only purchasers aged 35 or over purchased rump steak, pot or rib roast or shin. None of the under 34 year olds were planning to roast a joint while 15-20% of the older categories would do so. The younger age group are more likely to fry their beef (more than 35%). More than half of all age groups were planning to cook their beef by one of the quicker methods, either on the hob, grilled or fried. This proportion increased to nearly 80% of those purchasers under 34 years of age.

Figure 2. Effect of consumer age on frequency of consumption of beef (1060 consumers)

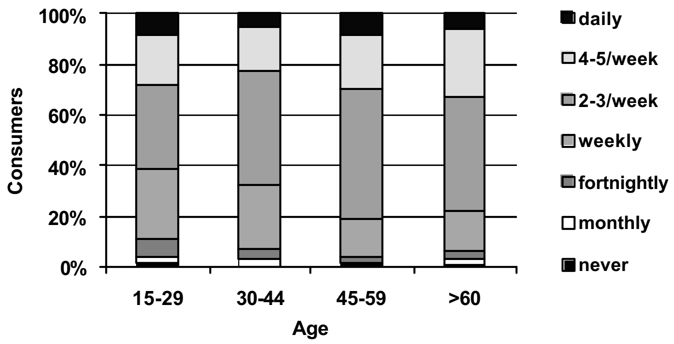
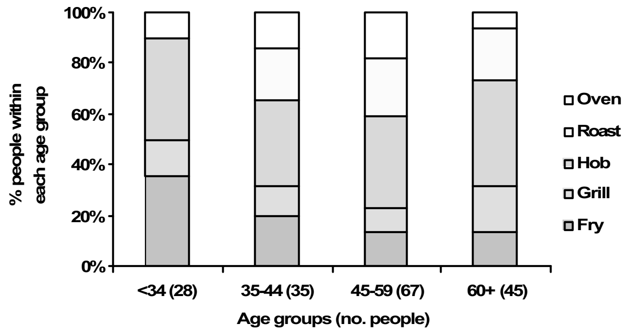


Figure 3. Effect of purchaser age on planned method of cooking



Effect of age on sensory satisfaction. Age of the purchaser significantly affected several aspects of their satisfaction with the beef they purchase. Those least satisfied with the fat content of beef were those in the 35 - 44 age range, with the youngest and oldest groups less concerned (Figure 4). This may relate to the increasing health education of the public combined with the traditional lack of concern for such issues of the young or, indeed, with the heightened concern of parents with these issues! In contrast, the purchaser's satisfaction with the juiciness and flavour of beef increased significantly with age, i.e., the younger age groups were least satisfied (Figures 5 and 6). A similar but non-significant effect was observed for tenderness. A survey of 530 consumers of beef showed that the mean sensory scores given for roast beef were lowest for the youngest age group (Figure 7). However, this effect was not observed for grilled beef, perhaps due to the greater acceptability of this cooking method to younger people.

Figure 4. Effect of purchaser age on satisfaction with fat content ($P<0.05$)

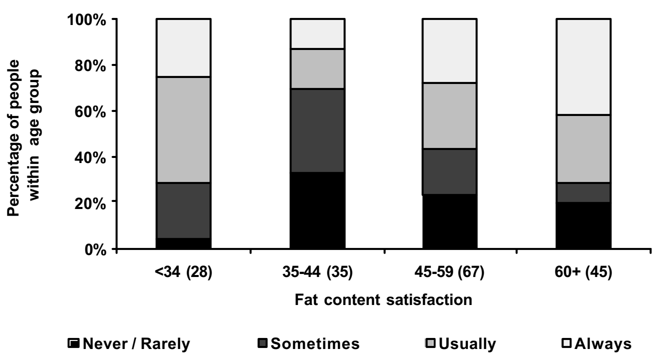


Figure 5. Effect of purchaser age on satisfaction with juiciness ($P<0.001$)

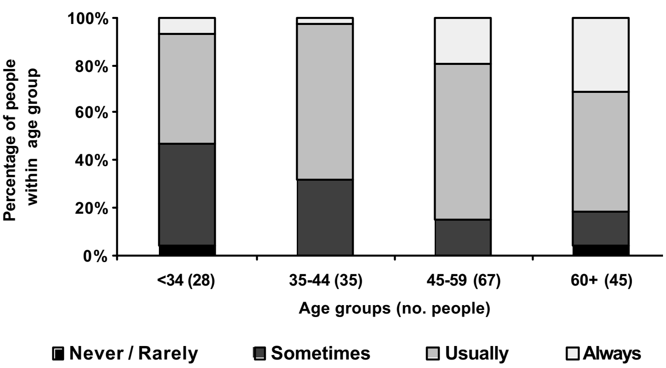


Figure 6. Effect of purchaser age on satisfaction with flavour ($P<0.05$)

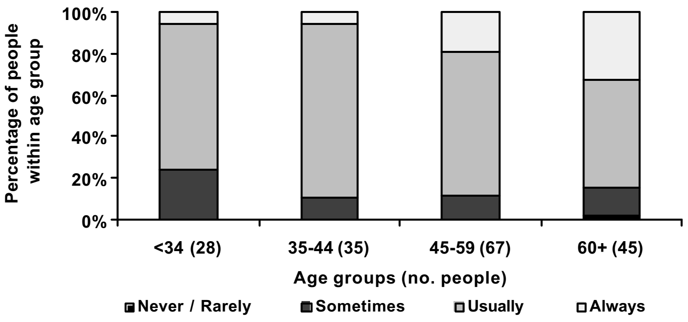
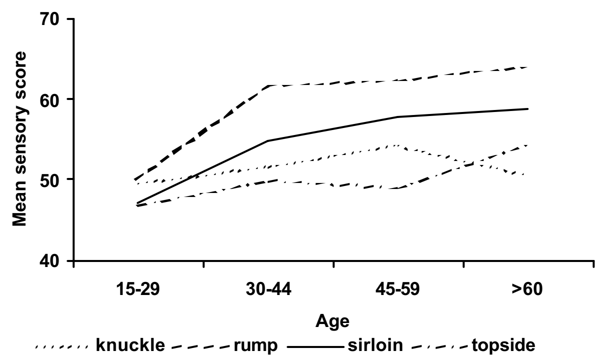


Figure 7. Effect of consumer age on overall liking of roast joints (530 consumers)



These data illustrate not only the changing habits of the new generation of beef consumers but also how their satisfaction levels with the traditional product are decreasing. One answer to this trend is to determine the expectations of the younger generation and then ensure that the beef produced meets those expectations. This requires management of the eating quality of the product.

Prediction and management of beef eating quality
The goal of the many studies conducted by others and ourselves on the factors that affect eating quality is, through an understanding of the underlying factors, to be able to predict and manage the eating quality of the final product to meet the needs of consumers. However, this is made more difficult by the many interactions that can occur between the many factors applying to the production, processing and the preparation of meat. Two main approaches have been used to address this problem. The first approach is to use one or more instrumental methods to predict the eating quality of meat from some property of the raw meat, while the second is to attempt to manage eating quality through management of production and processing.

Prediction of eating quality by instrumental methods. Amongst the instrumental methods tested are several spectroscopic methods. In Northern Ireland studies, near infrared reflectance spectroscopy gave useful predictions for compositional aspects (dry matter, crude protein, intramuscular fat). Correlations with juiciness were high, but correlations with eating quality scores for tenderness and flavour were poor (Park *et al.,* 2002). In contrast, the novel application of Raman spectroscopy for the prediction of meat quality gave good correlations between Raman spectroscopy data and tenderness (R^2 = 0.65), juiciness (R^2 = 0.62), acceptability of texture (R^2 = 0.71), and overall acceptability (R^2 = 0.67) is obtained by a sensory panel (Beattie *et al.,* 2004a).

Management of eating quality. Another approach is to use a system that either controls all those factors that could affect eating quality or uses them to predict the final quality of the meat. A number of systems are currently in use throughout the world. Some aim to provide assurance to the customer of provenance, welfare and other issues (e.g., Northern Ireland Farm Quality Assured Scheme) while others aim to minimise the risk of tough beef by controls on processing and other procedures (e.g., UK MLC Blueprint, New Zealand Qmark system). Other schemes aim to grade the eating quality of beef so that appropriate qualities can be used for specific purposes (e.g., USDA and 'Meat Standards Australia' (MSA) systems). In particular, the MSA system uses a model to predict the final eating quality, taking account of the many relevant factors and the interactions between them.

Current research conducted in DARD Science Service is aiming to adapt or develop a system suitable for predicting and managing the eating quality of Northern Ireland's beef and a collaborative research trial with the industry and Meat and Livestock Australia is being conducted to evaluate whether a modified system could work in Northern Ireland. Data is being recorded that will enable the bases of these various systems to be compared.

Conclusions Surveys of purchasers and consumers of beef show that the younger age groups are less easy to please and eat beef less frequently than the older generation. They are also more inclined to cook it using a quick method, such as frying rather than roasting or oven cooking. For these reasons the tenderness and flavour of meat will become of increasing importance in the future, if consumers' needs are to be met. A range of production, processing and preparation factors can affect these attributes and the production of beef with good eating quality is affected by the interactions between these factors. The beef industry in Northern Ireland, as elsewhere in the UK, is having to change to meet new consumer needs and new market forces. The beef industry and local researchers are working together to determine how science can be used to underpin the eating quality of Northern Ireland's beef.

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Improving the eating quality of beef: optimising inputs in production and processing

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Introduction There is increased interest in the eating quality of meat as opposed to factors such as growth rate and carcass composition which producers have mainly focussed on up to now. For beef, some of the factors affecting yield also affect eating quality (Thompson, 2002) but processing factors are possibly more important. Early work conducted at the University of Bristol, was incorporated in to the blueprint 'for improved and consistent quality beef' (MLC, 1991) and has attempted to improve the level and consistency of beef eating quality. This presentation summarises the background to this area and some of the recent studies conducted at Langford.

Production effects on tenderness, juiciness and flavour. Consumer research on beef eating quality has shown that the most important attribute in determining acceptability is tenderness, but when tenderness is increased and variability decreased then flavour increases in relative importance (Warkup et al., 1995; Koohmaraie this conference). The latter concludes that, discounting the effect of Bos Indicus, 'on average, most breeds are fairly similar in meat tenderness. However, there is more variation within each breed than among the most different breeds'. In one of several studies sponsored by the MLC it was concluded that genotype and fatness had little effect on the eating quality of steaks of progeny from dairy dams across six sire breeds (Hereford, Aberdeen Angus (AA), Charolais, Limousin, Belgian Blue (BB) and Piedmontese) (Homer et al., 1997). BB did produce higher tenderness scores for roast topside. But Campo et al., (1999) found that meat from double muscled BB was tender soon after slaughter, tenderised little thereafter and any tenderness advantage over meat from other breeds was lost when meat was conditioned beyond 14-21 days, a practice now widely practiced in the UK. Using pure bred steers to study the effect of growth rate on eating quality, Sinclair et al. (2001) concluded that AA had a small tenderness advantage over Holstein, Charolais being intermediate, and an advantage in terms of juiciness, flavour and overall acceptability compared to both other breeds. Comparing pure-bred Angus, Simmental, Charolais and Limousin steers finished to the same intramuscular fat content, Chambaz et al. (2003) showed that Angus were the youngest at slaughter and fastest growing, Limousin the oldest and slowest growing, yet these two breeds produced meat which was more tender than the other two. No other measurement, pH, rate of temperature fall, collagen content and solubility, sarcomere length, overall fatness, explained these results.

The role of breed in flavour development is contentious. It is often assumed that the traditional beef breeds, such as Aberdeen Angus, have the best flavour and dairy breeds the worst although there is little scientific evidence for this. In one study we found no difference between Holstein-Fresian steers and Welsh Blacks (Vatansever et al., 2000). Koch et al. (1976) found that Jersey and South Devon crosses produced more tender and juicy meat than that from traditional; beef breeds. This is possibly because in dairy breeds taken to the same level of finish, intramuscular fat is higher.

Bulls. Generally young bulls have been found to produce tougher meat than steers or heifers and this held true in the studies conducted at Bristol for the MLC Blueprint and in more recent experiments again at Bristol. Bulls were generally tougher than steers at equivalent age points (12, 14 and 16 months old) but bull beef could be tenderised by conditioning/ageing for 14 days. Bulls with beef genes (from the suckler herd) were more tender than those from the dairy herd (Fisher et al., 2001). Hence, conditioning meat from young suckled bulls can produce an acceptable product.

In a further trial, bulls were slaughtered at 15, 17 and 19 months of age coming from production systems that produced a finished animal of similar weights at those ages. Half the animals from each age group were from a suckler herd and half from a dairy-cross system. They were compared with steers from the two same systems that were finished at 24 months of age. Seven of the 80 bulls produced DFD carcasses (an indication of stress in the period leading up to slaughter), which affected their sensory attributes. This data was removed to give a clear picture of the overall trends. Dairy-bred bulls and steers tended to produce more tender and flavoursome meat than suckler bulls, in contrast to the previous project, but differences were small and statistically non-significant. Overall, steers produced the most tender meat, with toughness increasing in bulls as age increased from 15 to 19 months of age. Meat tenderised with conditioning in all groups with the improvement between 9 and 21 days being greater than that between 21 and 35 days. The 15 and 17-month suckler bulls approached 9-day conditioned steer values for tenderness after 21 days conditioning but the 19-month suckler bulls did not approach 9-day steer values at 21 or 35 days. The 15 and 17-month dairy bulls approached the tenderness of the 9-day conditioned dairy steer meat only after 35 days conditioning.

There were no consistent effects of sex status or conditioning on juiciness. Flavour improved slightly with 21d ageing but then declined. Abnormal flavour increased from 21-35 days ageing. Steers and the oldest bulls tended to produce the strongest flavoured meat. It was clear that tenderness increased with conditioning time, abnormal flavour increased and beef flavour decreased from 21 to 35 days conditioning and overall flavour liking and overall liking paralleled that of beef flavour.

Whilst there is a widely held belief that good nutrition, and hence growth rate, affects tenderness, there is little clear evidence for this. Perry and Thompson (2005), in a large study during the development of the Meat Standards Australia system (MSA), showed a small positive relationship between increased growth rate and increased tenderness within a group of cattle, but not between groups. It is widely believed that a proportion of concentrate is required in the diet to give a rapid growth rate and hence tender meat, yet when silage-fed cattle were introduced to a silage/concentrate mix at various times during finishing, the earlier the introduction of concentrate the tougher the meat, except for those finished on the mix throughout (Moloney et al., 2001).

Maher et al., (2004a,b) conducted trials to establish the effect of homogeneous pre- and post-slaughter management on tenderness. They produced steers with one common BB sire raised to a common management pattern and processed with hip suspension, considerate cooling and ageing and compared them with randomly produced steers processed in the same way and with steers randomly selected from two commercial plants and conventionally hung and randomly chilled. A controlled processing regime reduced the variance in tenderness compared to the randomly processed samples. Homogeneous production of steers did not reduce variance in tenderness compared to those produced at random but processed in the same way. In a similar manner, Tatum et al. (1999) applied a total quality management system to the production of beef meat, applying critical control points at genetic input, pre-harvest management, early postmortem management and during conditioning. They also reduced overall variance in tenderness, but still produced 0.12 of animals with tough steaks. Non-conformance amongst sires suggested that control of genetic input would reduce variance further.

Post-slaughter factors. Post farm gate factors are also important for flavour variation by changing the concentrations of tissue components, which produce specific flavours in the cooked meat. Conditioning (ageing) is probably the most important factor. However, both research (Spanier et al., 1997; Jeremiah and Gibson, 2003)) and industry experience is that longer conditioning under some packaging conditions produces 'bland' flavours. Ageing on the bone is thought to produce different flavours from that done in vacuum pack, but Jeremiah and Gibson (2003) found that bone-in meat aged in vacuum had higher beef flavour intensity than that aged on the carcass or boned out and aged in vacuum. Campbell et al. (2001) found few significant differences, whilst Warren and Kastner (1992) found consistent positive effects of dry ageing on improving flavour. In a recent study we found a trend, but no significant improvement for meat aged on the bone rather than in vacuum pack (Warren et al. in preparation)

When carcasses are chilled rapidly they toughen due to cold shortening (Locker and Hagyard, 1963). The simplest way to avoid cold shortening is to ensure that the carcass does not cool below 10°C before the muscles have gone into rigor. As a rule of thumb this has been taken as 'not below 10°C in 10 hours' from slaughter (Bendall, 1972). This is inconvenient in rapid-throughput plants and may be difficult to achieve in winter when the ambient air temperature is low without setting up temperature controlled chillers which do not reduce air temperature below 10ºC in the first 12h. It is extremely difficult to apply to carcasses which vary in conformation (muscle mass) and fat cover and which may be entering the chiller first, when it is at its coldest, or last when the rate of chilling will be much reduced. The solution was the introduction of Low (LVES) or High (HVES) Voltage Electrical Stimulation and/or hip suspension. Electrical stimulation prevents muscle shortening by removing energy stores (glycogen) and HVES, in particular, may have other tenderising effects. Hip suspension holds commercially important muscles in a stretched position, again preventing shortening. These processes allow more rapid chilling and hence more hygienic production and reduced conditioning times.

The MLC Blueprint for tender beef recommends a number of measures during processing (LVES or HVES, hip suspension and/or considerate chilling alone, or in combination with a conditioning period) and the MSA system gives bonus scores to carcasses that have been stimulated (Thompson, 2002).

The whole chain approach. It is clear from the above that there may be many small factors operating throughout the meat chain that contribute to the eating quality of beef. The MLC Blueprint was designed to address some of the critical points in the production and processing chain. Individual companies have developed this to their own standards and are taking a whole chain approach in partnership with producers, feed manufacturers, processors and retailers.

The Scottish industry, through Quality Meat Scotland (QMS) took an early lead in the development of Quality Assurance Schemes (QAS), achieving accreditation to European EN45011 standards and establishing a strong link with marketing and promotion activities. They believed that identifying industry best practice for consistent eating quality would add to the QAS and lead to a distinctive quality brand. This was the focus of a project sponsored by SEERAD, and involving the Scottish Beef Industry, through QMS, and designed to test a package of best-practice techniques, both on-farm and in-abattoir, on the eating quality of Scottish beef as assessed by a trained sensory panel and a recruited take-home panel.

HVES, LVES and hip suspension have been tested in previous research but it is clear that many plants do not like hip suspension as it is labour intensive, carcasses require more space and butchers must be retrained to cope with the differently shaped cuts. Others believe that 'considerate' chilling and traditional conditioning will provide a superior product. This project provided the opportunity to test these systems in several abattoirs under commercial conditions. Hence, a combination of LVES, hip suspension and conditioning was tested in one plant and HVES with conditioning in another. Other combinations were tested as a consequence of taking random samples from the rest of the major industry plants in Scotland, as per the specifications they use currently, without any intervention from the research consortium.

Materials and methods Thirty two farms in Scotland produced cattle to the enhanced on-farm protocol. They were steers or heifers only, with a minimum 75% beef genetics, which had been suckled for least 5 months. They were finished on grass, or mainly preserved grass-forage, with concentrates in the winter, and grew at greater than 0.8 kg d^{-1} in the finishing period. Farmers were given written guidance for on-farm protocols and were inspected at least once during the growth period. Licensed hauliers, who were part of a QA scheme giving particular regard to good welfare practices, transported animals to the abattoir. Cattle from two farms were slaughtered through each of two commercial abattoirs on eight occasions between March and December 2003. Cattle with no prior known history were randomly selected from two farms submitted on those days to act as a basal group. In the abattoir, the groups of cattle were divided between an enhanced abattoir treatment and a standard abattoir treatment.

In one abattoir the advanced treatment was high voltage electrical stimulation (HVES) (which could be applied to one carcass side after carcass splitting and not to the other which formed the basal treatment side) and in the other low voltage electrical stimulation (LVES) and hip suspension. Carcasses were monitored through the abattoir for weight, grade and pH at two and 48 hours post-slaughter. Loins (*m. longissimus thoracis et lumborum*) from two sides from each farm and abattoir treatment were selected for submission to the taste panel. Enhanced-processed samples had to be from carcasses weighing 260-400kg, with a minimum of fat class 3 and conformation of E, U or R having a pH greater than 6.00 at 2h and less than pH 5.80 at 48h postmortem. Basal samples were taken at random from the specified groups.

Samples were frozen after 7 (basal) or 21 (enhanced) days post-slaughter, stored until balanced sets had accumulated then thawed overnight, cut into 20mm thick steaks and grilled to a centre temperature of 74ºC. Two samples from one enhanced farm with both basal and enhanced abattoir treatment and two from a basal farm were tested in the same session. They were scored on an 8-point scale for texture, juiciness, beef flavour intensity and abnormal flavour intensity. The take home panel were given these same samples, one a week over four weeks, and were asked to cook samples as normal and to score samples on an 8-point category scale for the acceptability of the same attributes as the taste panel with the addition of overall acceptability. The trained taste panel results were analysed, adjusted for assessor and order of testing, using Genstat and a model with several random (error) terms and fixed terms fitted with Residual Maximum Likelihood (REML).

Results Cattle were sourced within specification and the experimental design was effective in detecting statistically significant differences within attributes of 0.1-0.2 units on the 1-8 scale. Pre-slaughter enhanced protocols had little effect on overall mean eating quality scores as assessed by either the trained taste panel or the take-home panel. It is probable that the basal farms sourced by these abattoirs were rearing cattle to a good specification within a registered scheme. There was a clear and highly significant effect of abattoir processing treatment on the eating quality of the meat (Table 1), the enhanced treatment producing an increase in rating for texture of over one unit, which is very large in sensory terms. The effect on flavour was an increase of 0.2 units, which is still highly significantly different.

Table 1. The sensory characteristics of beef, assessed by a trained taste panel, according to processing category

Production	Basal	Enhanced	Sed	Sig.
n	128	128		
Texture (1-8 scale, high = more tender)	4.06	5.09	0.077	***
Juiciness (1-8 scale, high = more juicy)	4.75	4.68	0.057	ns
Beef flavour (1-8 scale, high = stronger flavour)	3.59	3.78	0.036	***
Abnormal flavour (1-8 scale, high = stronger flavour)	2.79	2.76	0.043	ns

Table 2. The carcass and sensory characteristics of beef, assessed by a take home panel, according to processing category

Processing	Basal	Enhanced	Sed	Sig
n	60	60		
Tenderness (1-8 scale, high = more likeable)	5.63	6.43	0.144	***
Juiciness (1-8 scale, high = more likeable)	5.89	6.39	0.113	***
Flavour (1-8 scale, high = more likeable)	5.99	6.37	0.122	***
Overall acceptability	5.78	6.43	0.133	***

The take home panel cooks saw a significantly lower amount of purge, or free liquid, in the bags containing enhanced abattoir samples. The families rated the enhanced abattoir processed samples much more highly for texture, juiciness, flavour and overall acceptability than basal processed samples (Table 2). The biggest differences were for texture and overall acceptability. They showed a preference for the juiciness and flavour of the enhanced samples, though the sensory panel found no difference in juiciness.

Table 3. Sensory characteristics of beef, assessed by a trained taste panel, according to processing category and abattoir

Abattoir	Plant 1		Plant 2		Sed	Sig	
Processing	Basal	Enhanced	Basal	Enhanced		Plant	Interaction
n	64	64	64	64			
Texture	3.95[a]	5.25[b]	4.18[a]	4.92[b]	0.178	ns	***
Juiciness	4.62 [a]	4.42 [a]	4.88 [b]	4.93 [b]	0.100	***	*
Beef flavour	3.55	3.76	3.64	3.80	0.077	ns	ns
Abnormal flavour	2.72	2.74	2.85	2.79	0.111	ns	ns

Results showing the application of basal or enhanced procedures in two different abattoirs are shown in Table 3. There was an interaction for texture indicating that the samples in the two plants reacted differently to the enhanced processing (two different forms of electrical stimulation). Whilst the ultimate texture of the enhanced processed samples did not differ significantly between plants, those from Plant 1 started at a lower baseline and hence improved more. Hence, the two different processing procedures at the two plants resulted in the same improved tenderness. Conversely, samples from Plant 2 were juicier than those from Plant 1 overall, despite the latter carcasses being one grade fatter on average. There was an interaction with processing, as samples from Plant 2 became juicier with enhanced processing whilst those from Plant 1 became less juicy. This relationship has not been seen before and is difficult to explain. Samples behaved in a similar manner at both plants for beef flavour and abnormal flavours.

Table 4. Comparison of sensory panel attributes across basal processing, enhanced processing and industry random baseline samples adjusted for differences in gender

	Processing				
Attribute	**Basal**	**Enhanced**	**Industry**	**Sed**	**Sig**
N	128	128	128		
Texture (1-8 scale, high = more tender)	4.00 [a]	5.02 [b]	4.71 [b]	0.171	***
Juiciness (1-8 scale, high = more juicy)	4.71	4.64	4.63	0.100	ns
Beef flavour (1-8 scale, high = stronger flavour)	3.54 [a]	3.73 [b]	3.55 [a]	0.068	***
Abnormal flavour (1-8 scale, high = stronger flavour)	2.83 [a]	2.81 [a]	3.09 [b]	0.086	*

The purpose of taking industry random baseline samples was to provide a snapshot of eating quality across the industry, from a wider sample than the two abattoirs taking part in the testing of enhanced practices. The industry random baseline samples represented a wide variety of quality ranging from some of the best to some of the worst sampled in this trial. The average industry random baseline values for texture were between those for the basal and the enhanced processed samples (Table 4). Numerically at a value of 4.7, the industry random baseline samples were, on average, less tender than the experimental enhanced processed samples, which had a value of 5, but these values were not statistically significantly different. They were very similar to the basal samples in flavour and statistically inferior to the enhanced processed samples and had significantly more abnormal flavour than either the basal or the enhanced processed samples.

Results for eating quality showed that substantial proportions of variation were attributable to individual farm and individual animal, although the precise causes of this variation remain poorly understood. They are not, in the main, associated with factors we were attempting to control via the enhanced farm protocol (although 'best practice' may have been applied in both enhanced and basal farms). There is within-breed genetic variation in many meat eating quality characteristics, and this explains some of the individual animal variation. It is notable that 0.22, 0.54, 0.39 and 0.62 of the variation in texture, juiciness, beef flavour and abnormal flavour respectively could not be explained by any of the factors measured in this trial. To some extent this was to be expected. This field trial was designed to test a commercially applied package of measures expected to improve eating quality, rather than to precisely apportion sources of variation; a tightly controlled experiment might have allowed more of the variation to be accounted for. However, these results are useful in demonstrating that the MLC Blueprint works in large scale practice and in highlighting areas where we need a better understanding to control variability in meat eating quality more effectively.

In conclusion, a combination of HVES, or LVES and hip suspension, with two weeks longer conditioning time, produced a highly significant improvement in beef loin steak eating quality, both methods resulting in meat of similar eating quality and reduced variability. These results are similar to those of Maher et al. (2004b) in that careful post-slaughter treatment had a greater effect in reducing variance in tenderness than did pre-slaughter factors. However, there are still sufficient animals within the enhanced group, which showed poor tenderness, and warrant other avenues of research. A genetic approach to eliminate those carcasses that produce tough meat, whatever the post-slaughter regime, might be one way forward.

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Integration in the beef supply chain

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Introduction The beef supply chain has evolved over a number of years through a network of growers, rearers, finishers, marketing groups, markets and dealers. The result of this is a mix of cattle breeds and finishing systems that will offer the meat processor and end customers a variable beef offer. This does not necessarily mean a poor quality product, but variable quality will not give customers confidence in buying the product on a regular basis.

This supply chain also creates its own problems, as cattle are not readily available when customers wish to purchase certain cuts and therefore retailers must purchase beef from outside of the U.K to satisfy consumer's demands. From an abattoirs perspective this is not good news, as the production lines require optimum volumes throughout the year to remain cost effective.

This presentation highlights the benefits of developing an integrated beef supply chain and also demonstrates how those within the chain will find added benefits.

The UK Beef Supply Chain Beef production, currently is relatively un co-ordinated as animals are grown through rearing and finishing systems and sold as they become ready for slaughter from 14 months of age to up to 30 months of age depending on the production system.

Lets start at the very beginning of the current U.K production cycle.

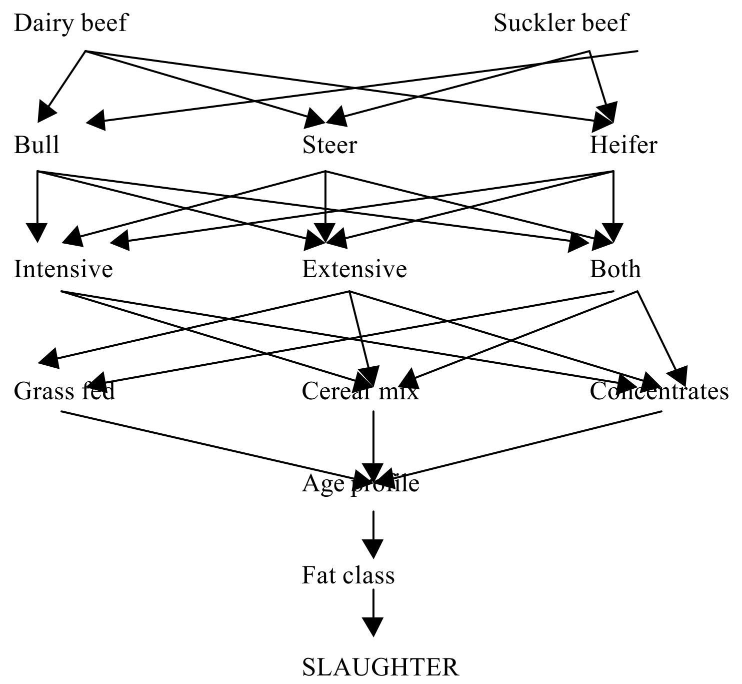
Calves are available from two areas that are better known as beef suckler herds or dairy production herds.

Beef Suckler herds Cows are bred using quality beef genetics to consistently improve carcase quality and are therefore good in confirmation and growth rates. These herds are used to produce a calf on an annual basis and the cost effectiveness of the herd is completely dependant on sales of the calf sales as either weaned calves sold as store cattle or finished on farm and sold to beef processors. Cows need to produce and rear one calf per year to remain cost effective, as this calf is the only crop that the cow produces. Cattle from this sector would account for just under half of all cattle sold in the U.K.

Dairy herds Cows are bred for their ability in producing high yields of milk and are generally of a poorer carcase confirmation compared to beef breeds. Calves are produced on an annual basis and are effectively a by-product of the dairy industry apart from purebred females that are used as dairy herd replacements. Dairy farmers select pure beef bred semen to take advantage of the demand from beef growers and finishers from dairy bred beef.

The calves are then either reared or finished on the unit but in most cases are sold at 7 to 10 days of age through auction markets or dealers to calf rearing units and grower finishers. In most cases these animals are sold on at least once again to farmers that take them on to the next stage in their growing period. Dairy bred cattle would account for the remainder of the cattle sold in the U.K (over 50%).

Summary of The production Cycle In all cases the animals are produced with very little co-ordination to the timing of the sale and as to where the stock are destined. This is not due to poor business practice but due to the fact that beef systems and abattoirs have not developed at the same rate as other proteins such as chicken or pork. This production cycle has been in place for many years and has worked during periods when farmers were paid subsidies and strong export markets offered higher returns. The removal of beef subsidies will result in more focus on reducing the time on farm of cattle due to more efficient beef finishing systems.



The Meat Demand Chain The meat demand chain is derived from consumer demand and the availability of raw material. In many cases the two do not match as consumers are driven by promotional offers and the weather that ultimately affects the "decision tree" of customers that relates to the mood of customers and what they want to purchase at any given time. A good example of this would be rump steaks that are the chosen cut by many customers during summer months as these can be cooked quickly and easily on barbeques. It is during the summer months that cattle become in short supply as farmers are concentrating on harvesting and cattle are unable to put the finish on required to enable optimum carcase confirmation to meet abattoir specification.

The result of this is that retailers need to purchase in certain beef cuts to satisfy the customers demands, as research has proven that customers that are unable to purchase all of their groceries in a "one stop shop" are unlikely to return on a regular basis and loyalties may lie elsewhere with a retail competitor. In this case such cuts may be imported through alternative supply channels. For a U.K beef operator this will reduce the efficiencies of the abattoir part of the business and will offer a potential competitor the opportunity to take shelf space. There is also of course the cost element to consider as imported meat can be produced more efficiently than beef slaughtered in the U.K due to lower labour costs and environmental costs, the end result being a comparative product at lower prices. The most important factor for any beef processor is to focus on customer requirements and find innovative ways in delivering them efficiently.

It is vital at this stage that we realise that a production chain is really a demand chain and by realising this and changing the mindset of producers and processors within this sector that we can really change production systems to match demand.

Consumer expectations within this demand chain are as follows:

- Product is always available
- It is safe (assured)
- It looks good
- The product matches up to expectations
- It is affordable
- It is consistent

To deliver the above and more we need to be in a strong position in terms of demand and supply chain and the two must match. The standard beef supply chain will not deliver on consumer requirements unless we change it. To do so we believe that closer relationships must be delivered in the form of full integration which means that providing retailer and beef processor are prepared to commit on a long term basis then beef integrated systems can be developed that will ultimately benefit all within the supply chain.

Blade Farming South West This is an example of the first beef integration system that was developed from Blade Farming Ltd in 2001, whereas a software system was developed that would ultimately give beef finishers the ultimate in efficiencies post the removal of beef subsidies in 2004. This system is managed by a team of livestock specialists from Southern Counties Fresh foods Ltd in Somerset and the objectives of the system are:

- To deliver on product differentiation on beef products
- To have a sustainable supply base
- To improve on the partnerships that already exist through the Southern Counties Beef and Lamb producers club
- To be in a position to offer retail customers large volumes of beef that could assist in high and low beef promotional activity that will ultimately lift sales and improve throughput in the factories to reduce overhead costs and down time
- To improve on assurances at farm level by understanding feed inputs at a more detailed level
- To reduce costs for farmers by cooperative bulk purchasing of feed and other inputs
- To improve the health status on and between farms by introducing simple and effective measures that will improve the returns to farmers
- To work with partners in the supply chain (feed, genetics and animal health)

Blade Farming SW will be in a strong position to generate a supply of beef that not only reduces the fluctuations in supply but also offers a more robust system that that of our competitors oversees. The added value to this is currently underestimated, as many beef production systems have not yet quantified the cost of inefficiency and improving health status.

Background The system began by offering forward base price contracts to beef growers, which enabled Southern Counties Fresh Foods to secure volume through periods where cattle availability became scarce. The abattoir very quickly realised that this not only offered benefits to customers in the demand chain a more consistent beef offer, but also less down time in the production lines that resulted in a contribution toward the over head cost of running a very labour intensive business. SCFF decided at a very early stage that this could and should be a major part of supply into the company.

Farmers that signed up to a contract could also see the benefits of contracting to a beef processor as they were spending far too much time in marketing their cattle and realising that waiting for prices to rise was costing more money in the production cycle as days on feed are key to a profitable beef enterprise.

There was a key issue that none of us had recognised. This was the supply of reared calves in to the finishing units, as previously we had assumed that existing calf rearers would fulfil our farmer's requirements and ours. This was clearly not the case, as most of the calf rearing organisations were not focussing on their customers (farmers) requirements as many batches of calves reared varied in age, breed and weight on delivery to finishing units. This meant that finishing beef units had little or no chance in becoming efficient as the Blade SW system was reliant on an all in all out operation to allow for maximum utilisation of the beef buildings.

To ensure that our Blade SW system would be effective we decided to develop our own rearing units that would completely change the scale of our organisation for good. We opened our first unit in Langport and very quickly two others were implemented and now another two are in place.

All of the units work to a strict protocol that includes a strict procurement model to ensure quality stock is procured to a strict specification. This immediately gave us a quality raw material that we reared effectively using quality feed and milk powder purchased effectively. The units are measured on performance and rearers paid on health performance and are keen to maximise performance in their buildings. Their customers (beef finishers) had the opportunity to reject reared calves out of specification that improved the rearers performance.

The system grew in volume very quickly as from the launch in 2001 the system now boasts 12500 cattle per year in to the abattoir and a demand from farmers not in the franchise finishing model for calves has arisen.

A contract with a retailer is now in place with a number of contract finishers on a cost plus mechanism that has ensured beef farmers have a return provided that remain efficient, and supply the demand chain with a commodity that is better than other beef commodity offers available. This is a first and is available to consumers in July this year. In fact this has already gone to another level as cattle in this system will be changed over time to a certified South Devon breed as this can improve the offer to consumers and a promotional programme has already been calculated and implemented.

The story is far from over as within this integrated business a bio secure model has been developed with a global chemical company – Ecolab. The objective was to remove further costs from our system and by implementing strict codes of practice on our rearing units we found that mortality rates were improved as well as growth rates. These kits are being rolled out over time to all of our units and are commercially available to other farm enterprises.

Summary Beef integration has not only satisfied the demand chain but also improved relationships with all those involved. True partnerships mean that if anyone was to leave the partnership then they would have an effect on others involved. The Blade SW model is a demonstration of this ethos. Not only are customers benefiting from this system but innovation is evolving new ways on taking cost out and improving farm standards and we believe that a low cost best practice model will take Blade SW, participating beef producers and Southern Counties fresh Foods into new markets.

Beef quality – a Northern Ireland perspective

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Introduction Quality is defined as the combination of its characteristics that make one piece of meat more valuable than another to the purchaser. In this context the purchaser may be the abattoir that first purchases animals from the producer, or the consumer who makes the final purchase for consumption. The characteristics that contribute to beef quality may thus vary according to who the purchaser is. For example the abattoir is likely to take the view that characteristics associated with the live animal and its carcase, such as its grade, breed, sex, production method, feed type, assured status and lifetime traceability, make one animal or carcase more valuable than another. Whilst it is recognised that the quality of the eating experience is the ultimate assessment of quality to the final consumer, there are other characteristics that might be important such as value for money, pack price, colour, visible fat, nutritional value, healthiness and safety, some of which may contribute to the consumer's perception of what the eating quality might be.

This presentation will take a Northern Ireland perspective on some issues on which 'industry' needs to decide the way ahead for the future. It is therefore not for the author to present the answers, rather the challenges for 'industry' over the whole supply chain from producer to consumer, and the stakeholders therein, including Government. The issues identified are the 'quality of production' and the assurances that may or may not be required in the future, the 'quality of legislation and its enforcement', the 'quality of traceability', and the 'quality of consumer information'.

Quality of production – assurance The organization of assurance leaves much to be desired. Although there are strict principles to be followed, the huge variation in the arrangements for implementing those principles casts doubt on whether the principles are being followed by everyone who is involved.

In the UK there are seven farm assurance schemes covering beef. The longest established is the Northern Ireland Beef & Lamb Farm Quality Assurance Scheme (NIBL FQAS), which was closely followed by the Scottish scheme now known as Specially Select Scottish Farm Assurance (SSSFA), what is now the English scheme Farm Assured British Beef & Lamb (FABBL), and the Welsh scheme Farm Assured Welsh Livestock (FAWL). Soil Association Farm Assurance (SAFA) covers organic beef, and beef as part whole farm assurance is a more recent offering in the English Midlands by Genesis QA. Attempting to be an umbrella body for these and other farm sector schemes is Assured Food Standards' Red Tractor Scheme. The term 'scheme' in this context is a rather ill-defined, usually informal collection of members or participants of no legal entity, and often described as 'industry owned'. The 'Product Standard' with which participants must comply in order to achieve certification as an assured producer is usually owned by the 'scheme'.

Verification of producer compliance with the Product Standard is conducted by Certification Bodies (CBs) which are accredited as such by the United Kingdom Accreditation Service (UKAS), accreditation meaning that the UKAS have determined that the CBs follow an operating procedures 'standard' known as EN45011. Such an operating procedure is also known as a Product Certification Scheme, and thus the word 'scheme' has a different connotation to that described in the previous paragraph.

CBs are legal entities, usually private companies. Examples are the European Food Safety Inspection Service (EFSIS), Checkmate International (CMi), Product Authentication Inspectorate (PAI), Scottish Food Quality Certification (SFQC), Welsh Food Quality Certification (WFQC) and Northern Ireland Food Chain Certification (NIFCC). CBs should be third party and independent of the assurance scheme membership and the Product Standard to avoid a conflict of interests. This is not always the case, as some CBs own the membership scheme (e.g. EFSIS own FABBL) and collect fees from members, although this could be regarded as producers purchasing services that would certify them to a standard set independently by another body. Thus it could be said that there is a potential conflict of interests as a CB could well wish to certify as many producers as possible in order to maintain fee income. Although not for beef, some CBs also own the Product Standard, and a potential conflict of interest is to set a standard that is relatively easy to certify generating quicker fee income, or a standard that is time consuming to certify for which fees could be increased. The Food Standards Agency (2002) reviewed these schemes and recommended that the Product Standard and its setting should be independent of the certification process.

The setting of Product Standards is governed by three core principles. These are the need to assure Food Safety, Animal Welfare and Environmental Care. AFS attempt to ensure equivalence between the various sector schemes, not always successfully. The Scots, who have an enviably high reputation for producing quality beef, are to be congratulated for achieving an agreement in principle for equivalent recognition from AFS and a high degree of approval by such bodies as the British Retail Consortium, without an environmental code in their Product Standard. They argue that the environment is a matter for Government, and now that we have Cross Compliance requirements, they could very well be right.

Cross compliance also has requirements in relation to Animal Welfare, Animal Identification and Traceability, and Good Agricultural Conditions. This raises the question "what is left for assurance schemes?" Farm Assurance, the means by which best practice and much Government legislation was voluntarily shown to be in place, could well have run its course and may now have had its day. This will be determined by whether there will be reward in the de-coupled era market for assured product. Will an assured piece of meat be more valuable than a non-assured piece? If not assurance will only be adding cost for no reward, and the challenge for the industry is to face up to this, and to get out of farm assurance if there is no reward from the market.

There is also anther challenge from European assurance, in the form of EUREP-GAP. This broadly means European Retailer Produce Group Accreditation Process. Its recently launched Integrated Farm Assurance (IFA) Standard represents a substantial "dumbing down" when compared to UK farm standards. As the name of the organization suggests it is mainly retailer driven, and this begs the question that the lower standard is to allow retailers to bring in cheaper imports and yet still claim that they are assured.

However the UK beef industry has higher levels of assurance for the whole supply chain through the Feed Assurance, Livestock Markets Assurance and Abattoir and Processing Assurance Schemes of Assured British Meat. Another challenge is to ask if these will be necessary in the future when new Meat Hygiene legislation comes into force.

Quality of legislation Cross compliance requires a 1% annual check of each regulation and measure. Thus the checking frequency for an individual farm is mathematically once every 100 years. This has very little 'quality' compared to individual beef farm checks at an interval no greater than 18 months, plus a random spot check of 10% of a scheme's members each year. There is no suggestion that cross compliance inspections should increase, rather that assured producers are not inspected again when they have in essence met cross compliance in their assurance requirements. However it is not out of order to ask why the cross compliance legislation is separated out for special enforcement – is that right, and is it unethical not to enforce other legislation with the same rigour?

Although farm assurance schemes were never intended to be the 'Government's policeman', there is no doubt that they successfully implemented legislation which Government never enforced, such as the legal requirement for Veterinary Medicines Records. However producers, with less production income in the future, will rightly question why they should pay to be checked for compliance with the law. The only argument in favour of continued farm assurance is if it brings benefits, and one possible benefit would be to have assured producers recognized by Government as low risk when it comes to selecting farms for cross compliance inspection.

Beef Labeling is another aspect of legislation that has neither quality of requirements nor a quality of enforcement. The requirement for fresh beef to be compulsorily labeled with the name of the Member State in which the animal was born, reared, slaughtered (origin MS may be used if it is the same for these three) and cut is implemented to a high degree in multiple retailers, but almost totally ignored in independent butcher outlets. Furthermore, there is a derogation from this labeling in circumstances where the beef has been 'processed'. Adding herbs, spices or water falls into the 'processed' category, and these simple additions to what appears to be 'fresh' beef seem to allow retailers to opt out of what should be an obligation to provide consumers with relevant information.

Quality of traceability Northern Ireland established a computerised animal traceability system in 1988. It has been developed over time and is extremely sophisticated and well refined for cattle. It has allowed Northern Ireland to avoid paper passport systems. Now known as the Animal and Public Health Information System (APHIS), it includes many functions in addition to routine cattle movements, such as routine disease testing and herd/animal statuses, and individual animal DBES eligibility criteria for export. It is not for the author to comment on the British Cattle Movement System or the proposed GB Livestock Register, save to say that they will only be useful if they are 'live' systems, which means the movement of any animal is instantaneously captures as it takes place (as it is registered).

Quality of consumer information In the new 'information society' in which we now live, there are a multitude of organizations seemingly knowledgeable about what consumers want to know. There is a challenge for industry to determine exactly what consumers want to know about their beef, not what any authority wants consumers to know. The proposed FSA 'traffic light' system for highlighting fat, salt and sugar content of food is a system that will damn foods as 'bad' foods when it should be acknowledged that there is no such thing as a 'good' or a 'bad' food, but there are 'good' and 'bad' diets. Furthermore FSA also categorise 'Meat & Meat Products' together when discussing which food groups are for example high in salt or fat. This fails to recognize major differences between fresh and processed beef.

Multiple retailers, in their drive for sales, do not always demonstrate the highest integrity in the descriptions of their products and often present misleading information to the consumer.

Conclusions There area number of challenges for the beef industry to resolve in relation to quality. These are concerned with whether one piece of beef is more valuable than another piece of beef. If there is no reward from the market, then the beef industry will be trading in commodity rather than a premium product.

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Future trends in the European beef industry: a global view

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Perspective On June 26, 2003 the future of European beef production was significantly changed with the adoption of the Fischler sponsored Common Agricultural Policy (CAP) reform, de-coupling direct beef production support. Since January 1st 2005, beef producers are free to determine what and how much to produce; their former direct subsidy entitlements are now paid under varying formulas and country schemes for cross-compliant farming. On average, 2003 direct payments to beef producers of €7.9 billion EU-15 (1) amounted to around €1.07 per kg of carcass weight produced. With current carcass prices in the range of €2.68/kg, a removal of nearly 40% from beef producers gross value realizations (well in excess of any potential profit margin opportunity), it may be prudent to anticipate that in the absence of direct payment incentives and current beef prices levels, future beef production may be significantly affected.

However, the EU beef industry, producing a little less than 95% of consumption, continues to remain highly protected due to significant import barriers. To anticipate the potential evolution of the EU beef industry within a global context requires an accounting of the effects these import barriers and their effects on the development of the global beef industry.

Background To fully understand the future trends in the EU beef market requires a short review of the evolution of the industry under the Common Agricultural Policy (CAP) environment and its effects on the industry over the past 40 years.

Common Agricultural Policy The CAP was introduced in 1962 as a means to increase agricultural production across the EU while providing stable markets and ensuring adequate domestic supplies to consumers at fair prices. At the outset, the EU relied on intervention purchases to set a floor price while imposing import quotas and levies to protect its agricultural industry. With support prices generally above production costs, EU agricultural production expanded rapidly. During the 1970's the EU became a net agri-exporter due to mounting domestic surpluses. Export refunds facilitated the marketing of surplus EU commodities at prevailing world market prices, or below.

During the 1980's EU policy makers began to address the implications of mounting intervention stocks and introduced limited reforms. The 1992 MacSharry reforms reduced or eliminated market support intervention prices for certain commodities and expanded direct production-linked support payments to producers. The Agenda 2000 reforms further accelerated support price reductions while increasing direct subsidy payments.

Mounting EU CAP expenditures, the EU membership expansion to 25 member states, continued over-production, environmental issues and WTO trade disputes were among many issues that motivated the Fischler reforms in 2003. The most far-reaching effect of the reform is the commodity-specific de-coupling of market distorting direct agricultural subsidies and the introduction of the single farm payment (SFP) for "environmentally responsible farmland stewardship". This has effectively broken the link between production and farm income and may usher in a period of a more market-oriented production mindset. The SFP component of the overall beef farming income will further degrade over the coming years, subject to modulation levies and sunset provisions, forcing a formerly controlled and subsidized sector to compete with other, generally non-subsidized, animal protein producers for the centre-of-plate market share position.

The Significance of Imports Barriers Although the CAP reforms over the past two decades have mainly focused on limiting production and reducing price support, little has changed with respect to the EU's policy on imports. For the beef sector this will be a critical area of concern going forward.

The CAP regime limits imports directly through TRQs (tariff-rate quota) and indirectly through regulations. These mechanisms have been left largely untouched and will continue to have a significant impact on both EU domestic and international production.

Supply chain requirements in the country of origin are controlled by a comprehensive set of regulations that governs how and where EU beef can be produced. This includes specific farm and feedlot regulations, abattoir regulations and government controlled recording systems. These regulations necessitate establishing EU specific supply chains for the production of EU beef products. It is these regulations (as well as the continued ban on growth promotants) that have limited North American access to the EU market and significantly limits Australia's desire to participate in this market.

Concessionary schemes, quotas and tariffs regulate the amount of beef that countries can export to the EU under preferential terms. Generally, beef imported under these rules attracts a 20% tariff and is allocated to exporting countries (Hilton quota) and EU importers (GAAT quota). Beef produced under EU regulations can also be imported into the EU out-of-quota; however this product attracts a levy of more than €3,000 per tonne plus a 12% tariff. Currently, out-of-quota beef is mostly imported from South American's Mercosur trading block. Commercial considerations restrict these imports to only high value beef cuts those that can remain price competitive despite the levy. The import of out-of- quota manufacturing beef is therefore not economically viable.

The ramifications of these import restrictions on the future of domestic production will be dependent on a number of factors:

a) EU beef import quotas are not expected to be increased significantly, at least over the short to medium term, and any future increase would most likely be in reaction to domestic supply bottlenecks and price pressures.
b) Increasing beef imports into the EU will require the exporting country to promote the increase of their specific EU supply chains. As beef has a long production cycle, the ability of a supply chain to respond to a possible increase in demand will be relatively slow.
c) Out-of-quota beef supply channels will be competed over by qualified least cost producers, which could be either a function of efficiency or currency movements.

The critical point about beef imports is that there are currently significant access restrictions to the EU market in place, a factor that may not measurably change over the near term.

The European Union Beef Market The current EU beef market with approximately 8,000,000 tonnes annual consumption and similar levels of production, ranks globally second in size for consumption and second for production. Despite negative demographics and changing consumer trends, this market will continue to remain a major global player.

The EU has a dominant global position in both production and consumption
2003 Statistics

Country or Region	Consumption (1000 MT CWE)	Production (1000 MT CWE)	Exports (1000 MT CWE)
USA	12,339	12,039	1,143
EU (25)	8,324	8,045	437
Brazil	6,273	7,385	1,175
China	6,274	6,305	43
Argentina	2,426	2,800	386
Canada	1,065	1,190	384
Australia	786	2,073	1,264

Source: USDA

Imports will continue to be restricted by the EU's tariffs, levies and trade barriers with most authoritative sources expecting imports to increase to no more than 600,000 tonnes over the medium term. (2)

Over the next 5-7 years, with imports not expected to exceed 600,000 tonnes, domestic production would have to be maintained at current levels to meet anticipated demand. However, the expected drop in EU beef production does suggest that there may be a looming market imbalance. Declining beef production will be driven by a number of important factors:

a) With more than 60% of the EU-25 beef production coming from the dairy herd, this source will be subject to the on-going decline in dairy cow numbers, a factor of continuing production efficiency advances.
b) Decoupled subsidies are expected to reduce overall beef production; suckler herd based beef production may have the strongest head wind.
c) Reduced beef production economics will further rationalise the industry, leading to production system changes. In the short term, these adjustments may lead to further interim drops in production.

Predicted production losses over the next 10 years have ranged from 0.3% to 2% per year. As a guide, an average production loss of 1.5% per year over this period would reduce EU beef production by more than 1,000,000 tonnes.

Meeting this deficit with imports could be difficult:

a) With a total global beef trade of around 5,000,000 tonnes, a 20% increase from the EU will stretch most supply chains
b) The quota system is not expected to be expanded significantly over this period.
c) Most exporting countries (except for S. America, Botswana & Namibia) are not actively expanding their current market share by increasing their EU-specific supply chain capabilities.
d) Production imbalances for exporters targeting EU out-of-quota high value imports could become a constraining factor.
e) Animal health issues, politics and currency exchange rates will remain wild cards, requiring costly hedging strategies, both for exporters and importers alike.

The foregoing would tend to suggest that over the medium term beef production could be in continued short supply while import barriers remain in effect.

With this economic environment, beef price levels within the EU will play a major role in determining the level of production that meets the status quo between consumption and supply from both domestic sources and imports.

In an under-supply situation the floor price is generally set by the most efficient production chain with the ceiling largely determined by the elasticity of demand. In a decoupled environment the entry barriers into beef production have been significantly reduced, suggesting that investments into beef production will focus more on return on equity rather than attempts to maintain farm income. As a general rule, investment into commodity based agricultural products is stimulated as and when returns exceed base interest rates plus 4%. Based on current dairy derived bull production cost models, the threshold price could be in the region of £2.10+/kg CCW.

4. Development of the EU beef industry

Anticipating future changes to the European industry from a global view requires an understanding of a number of key factors:

a) Europe, the world's second largest producer, is unique in that the greater majority of beef is derived from the dairy herd
b) Europe is unlikely to approve hormonal implants or antibiotic growth enhances – products that many major international beef producers are dependent on
c) Land use legislation and environmental policies will limit the development of large scale intensive beef systems that are common place in most other significant beef producing countries

Within this framework, a sustainable beef production system will need to evolve; a supply chain that fits within the opportunities and constraints that the EU regulatory environment provides. Based on evolution of some of the more mature global beef industries in a market oriented environment, a number of trends could be anticipated.

Herd Structure and Size The dairy herd will continue to dominate European beef production with output determined by the economics and direction of the dairy sector. The suckler herd may be expected to contract in size (mostly due to profitability constraints) from its present level of more than 13.5 million beef cows and move into agricultural areas that give this type of production a better economic advantage. As discussed previously, the rate of decline of the overall breeding herd will be critical to the industry's stability.

Cattle types The beef special premium was allocated for bulls at 7 months of age; with steers allocated two premia, the last after 20 months. This regime not only promoted steer production but pushed average steer age at slaughter to well over 22 months with carcass weights in excess of 320kg.

With the absence of direct subsidies and the continued ban on hormonal growth promotants, it would be expected that cattle types, carcass weights and age at slaughter will adjust in the new environment. Young bull production, if managed correctly, will have a clear cost advantage over steer and heifer production. The lower feed conversion and subsequently higher feed and overhead costs in producing steers should continually push down carcass weights and age at slaughter to levels that are more efficient from the entire value chain perspective. Overall, carcass weights would be expected to decrease as market forces promote more efficient production strategies.

Production systems Under current beef production systems the major constraints in competing against global competitors and other meat proteins may not rest entirely with the cost of production but also the inefficiency of the movement of goods and services along the production chain.

Like competing proteins (pork and chicken), beef systems will also most likely migrate toward specialized larger scale enterprises. As the size of individual units will remain constrained by environmental policy, it would be expected that more linked and focused beef supply chains will emerge that are able to effectively and efficiently manage a large number of smaller scale production units.

Regional Development As the beef sector becomes more competitive, areas within the EU that have a natural advantage should tend to concentrate beef production. In the UK for example, the difference in gross margin opportunity between a beef finishing unit in an optimal location and one in a less favoured area could be more than £50/head. Competition from other naturally advantaged EU beef producing regions will likewise be the primary profitability threat to the UK producer, ahead of any imports.

Beef quality and market development Beef quality specifications will again become the primary market driver, both from a consumer and producer perspective. Beef, no longer subject to age/premia restrictions will be marketed to optimum specification/performance convergence points, resulting in higher consistency (as with chicken & pork). Due to the inherent variability in beef, more detailed carcass specifications may evolve that will enable more effective differentiation against imports and other competing animal proteins.

Imports will continue to be an integral part of the European market. Domestic product will be much more successful if positioned strategically in the market against imported beef, differentiated on its own merits allowing for a meaningful brand recognition.

Processing Sector Reduced livestock volume and already existing overcapacity in the abattoir sector will tend to place considerable further pressure on the industry. Rationalization and restructuring may be the only way to deal with the new realities. Resistance to higher beef prices from the retail sector in the first instance, and ultimately by the consumer requires least cost supply chain solutions.

Conclusion For those EU beef value-chain participants that are able and willing to adapt to the new challenges, the future could offer significant opportunities, but still, the way ahead remains essentially uncharted territory with many cross road decision points. The EU will continue to be a dominant beef consumer and domestic production will need to be at substantial levels to meet this demand. Where and how this beef will be produced will be the key criteria going forward.

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Beyond reforms the system matters more than ever

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Introduction Beef production in the UK currently runs at around 2.2 million slaughter animals per year with roughly 50% each from the suckler herd and the dairy herd. The value of production at farm gate is estimated to be £1.159 million and used to attract subsidy payments of £928 million. CAP reform has focussed attention on the profit potential of beef enterprises without subsidy. The challenge of profitability without subsidy is huge and must take account of fixed and variable costs, animal and feed resources, the market and the system.

There is no doubt that subsidy has distorted beef production and for many the decision on whether and how beef should be produced needs to be revisited. The potential gap between expenditure and income can only be met through two routes:

- a contribution from the market place
- a contribution from better technical and financial performance

It is the latter, which we will address further.

Technical and financial performance How good is the system being employed? The ultimate answer lies in the question of profitability. If the system is not profitable then it is not good enough. Simple! But to start improving a system you need to know which areas to address and this is where "benchmarking" technical and financial performance against others is an invaluable exercise. EBLEX publish *Business Pointers*, which uses a sample of farms in England to set out costs of production to a net margin level for suckler herds and for finishing systems and shows levels of technical achievement.

The crude analysis of the most recent figures for suckler performance – be it a lowland or less favoured area suckler enterprise - shows there is around a £200 per cow difference in net margin between those in the top third of the sample and those in the bottom third. Equally for the finishing systems the difference is £230 per head for extensive finishing and nearly £260 per head for intensive predominantly young bull finishing. The fact that such differences exist should be encouragement for those at the lower end of performance because it means there is plenty of room to improve!

Simplified Enterprise costings for English Sucklers in 2003/4 (source Promar)

	Bottom Third	Average	Top Third
LFA Suckler (Sample 51)			
Output (after replacements)	242.15	271.06	300.33
Subsidy	196.79	243.08	265.77
Variable costs	129.83	126.34	130.32
Fixed Costs	315.68	297.39	245.80
Net Margin	***-6.57***	***90.41***	***189.98***
Lowland Suckler (sample 74)			
Output (after replacements)	216.53	244.40	270.97
Subsidy	208.52	224.37	231.20
Variable costs	143.65	119.96	109.09
Fixed Costs	334.69	275.66	213.03
Net Margin	***-53.29***	***73.15***	***180.04***

Simplified Enterprise costings for English cattle finishing in 2003/4 (source Promar)

	Bottom Third	Average	Top Third
Intensive (Sample 48)			
Output (after replacements)	233.81	269.91	311.49
Subsidy	166.02	189.38	216.97
Variable costs	287.96	253.55	225.99
Fixed Costs	102.85	81.30	60.77
Net Margin	***9.03***	***124.44***	***241.70***
Extensive (sample 64)			
Output (after replacements)	180.21	227.85	297.52
Subsidy	82.70	128.94	181.53
Variable costs	151.86	158.39	144.83
Fixed Costs	226.70	207.11	187.22
Net Margin	***-115.65***	***-8.72***	***146.40***

There are several layers at which a system can be examined. The most basic is the appropriateness of the system to the natural resources of the farm in question. Questions that should be posed include:

- What type of forage and feed production is possible and at what cost?
- Are the animals available to exploit these natural resources profitably?
- Will the combination of feed and animals allow a product to be produced that is in demand?

The era of direct subsidy has meant that, for some, the answers now to the second and third questions means a change of direction is required. Which breeds and crossbreds to use will be answered here and for many the choice of suckler cow has changed in recent years.

The next layer at which a system should be examined covers the production strategy and needs to answer questions like:

- What time of year should I calve the herd and over what period? When should I buy calves/stores and at what age?
- When should I sell my output?
- How does my beef enterprise compliment other farm enterprises?

When these questions have been answered the tactical management decisions, to run an enterprise from day-to-day, can be made, and the key performance indicators identified that will give a true reflection of the enterprise importance.

Sucklers – key points to examine Perhaps the most significant challenge in making improvements to a system of production is knowing how all the different parts affect each other. It is easy to talk about breed, feed and system as if they are all separate - but they are not. Changing one part of the system is bound to have knock-on effects for others and very often this leads to a virtuous spiral of improving performance.

Number of weaned calves The number of calves produced is a cornerstone of suckler production. There are several approaches to increasing the number of calves weaned per cow served. Leaving aside disease issues perhaps the most critical is cow feeding and target condition score. If cows are over fat or too thin then fertility declines. Accurate winter-feeding of suckler cows relative to their body condition score is the key. This means that cows need to be grouped according to body condition and fed appropriately. At a system level the choice of calving period is crucial because it affects the ease with which cow condition score can be managed.

Bull choice has a huge effect on number of calves produced. Firstly and most obviously the bull needs to be fertile. Buying a bull without a fertility check is not wise and there is a good case to be made for annual checks on all stock bulls before the breeding season starts. Assuming fertility is sorted out then the breeding values of the bull are the next most important factor. All major breeds produce performance records and by using the estimated breeding values a bull can be chosen which gives you control over calving ease, which affect calf survival and cow fertility.

Weight of weaned calves It seems obvious that the weight of calves at weaning is very important to the productivity of the herd. However there are many way of improving this besides feeding calves more and using faster growing bulls.

A simple move like reducing the calving period can have considerable benefits in increasing weaning weights as well as reducing production costs and easing of management.

At the same level of calf performance reducing the calving period from 20 (the national average) to 12 weeks increases average sale weight by 25kg and increases average sale age by 23 days, assuming the same sale date. Further cost savings stem from routine husbandry tasks and feeding regimes being simpler because batches of calves are of a similar age. Benefits accrue to de-horning, vaccination, creep feeding and re-breeding.

The bull is again a vital part of improving weaning weights. Within performance recorded beef cattle a bull can be selected using EBVs for high growth rate. Choosing the right bull can make 20-30 kg difference at weaning time.

Feed and Forage costs Cost of feed and forage is the largest part of the production cost in suckler production. Making the most of forage through a well-managed plan of forage conservation and grazing can be highly cost effective. In general costs are lowest when grazing takes priority over conservation. Sward height is a very useful guide to grazing. Silage making should not rule grass use. Reduced calving interval makes grassland management simpler**.**

Using cheap by-product feeds can offer considerable savings provided rations are formulated correctly. Knowing the feed value of any feed is essential for accurate feeding. Silage, straw, straights, cereals and mixes should all be analysed to ensure they are fed at the optimum rate and in the optimum combination. Body condition scoring of cows can reduce winter feed costs because cows are fed more accurately. Feeding one rate to ensure thin cows are adequately fed means average condition, and fat cows, are overfed. Accurate feeding means fat cows get less feed and thin cows get more leading to an overall feed saving.

Creep feed can easily cost more than necessary either through using it for too long or making it too high in protein. Four to six weeks prior to weaning is usually plenty long enough for creep feeding (unless conditions are extreme). Calves approaching weaning usually need extra energy not protein. Milk and grass supplies the protein needed but not the energy. A simple creep of rolled barley will work effectively changing to the finishing ration of 14% CP only in the final week or two before weaning.

Finishing In the absence of Beef Special Premium, beef producers must consider finishing their steers faster at a younger age to maximise returns while minimising costs. There is no longer any value in slaughtering steers at over two years of age.

The latest EBLEX cattle enterprise costings suggest that many producers could improve their net margins (excluding subsidies) by as much as £75/head by finishing stock more intensively over a shorter period, mainly through spreading fixed costs over a greater beef output and better feed conversion efficiencies obtained with faster growth rates.

EBLEX recommends managing steers by all four main continental breeds to gain at least 0.8 kg liveweight/day over their lives. A higher lifetime growth rate of 1.0 kg/day will enable steers to be finished at 18 months with little compromise in carcase weight. Faster growth rates can easily be achieved by adjusting diets, allowing feed to be used more efficiently for beef production. As live weight increases so does the proportion of feed needed just to maintain the animal. Rapid finishing minimises these maintenance feed costs.

A similar policy of faster finishing at a younger age is advocated for steers sired by British beef breeds, although a somewhat slower lifetime growth rate target of at least 0.7 kg/day is advised to avoid the danger of putting on too much fat too early.

The ability of cattle to grow is determined by their genetic potential and the feed offered, and again, using EBVs to select bulls that produce fast growing progeny will benefit the finisher enormously.

Conclusions The right system gives the best reward for the resources employed when combined with effective management. The challenge for today's beef producers is to understand, secure and exploit appropriate feed and genetic resources for their system. The very best operators are doing this now but a large section of the industry needs to improve if it is to become profitable.

The way ahead for the British beef industry

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Introduction The subsidy decoupling forced on the UK beef industry is a violent phenomenon. There is supposition that the UK can overcome the ball and chain of its super-high cost production systems by delivering increasing quantities of high provenance, grass fed, cross-bred, steer and heifer beef onto high return EU markets. Fingers are also crossed that domestic consumers will be persuaded that higher priced, home-produced beef will continue to be good value and that despite a helpful lift in market income farmers will be able to overcome the cost/income reality they must face up to now that the subsidy blanket has been withdrawn. More critical than previously suspected in any analysis covering the retention or otherwise of an economically and environmentally useful beef cattle population in the UK is the ex-farm price of slaughter animals. The continuation from 2007 of financially useful levels of Single Farm Payment (SFP) is also emerging as crucial and the ability of individual farmers to strip huge, previously tolerated, costs out of their businesses is equally important.

Case against imports The background music on the market is soothing. World demand for beef is strong and there are clear indications that global supplies are already tight. This brings with it general agreement that as long as the world economy continues to expand as projected there will be further consumption lifts in Russia and the Ukraine which should combine with even more interest in South East Asia to create a sellers market that not even increased production in South America can undermine. Nevertheless there is anticipation that the new half million tonne gap between EU production and consumption already predicted for the end of the year could quickly rise to at least one million tonnes and this has fuelled speculation on whether high cost-high price EU beef production can continue at the level necessary to maintain critical mass.

Import quotas and tariffs are among the Community's defences. This does not imply that the recent surge in out of quota deliveries at full tariff will ease because it is difficult to see how they can if EU production falls further short of meeting internal demand - which following economic advances in the ten accession countries could very soon increase. But the overview is that this will not turn into a tidal wave. This is because its ultimate defence is EU beef's genuine claim to be a special product backed by welfare, sanitary and environmental standards that are difficult to match and UK beef's claim to these qualifications, and the benefits it could yet receive as a result of them, may be even stronger?

There is ample evidence of the preference among the UK's multiple retailers, burger specialists and caterers for the domestic product. They have different emphases but the most general reasons for an unwillingness to consider long term reliance on high volume imports are mainly logistical. These include acceptance that:

Forward price contracts are difficult if the exporting country has a high inflation rate and an unstable economy.

Many of the world's largest beef producers are not committed to long term export arrangements and sell temporary surpluses on a short term, overspill, basis that is not attractive to regular, large scale, purchasers who need supply security.

Domestic beef is likely to have a longer shelf life than imported beef which dramatically reduces wastage as a result of colour changes and other indications of lack of freshness.

Retailers using UK beef are less likely to be embarrassed by empty shelves as a result of long distance interruptions to delivery schedules – some as a result of political instability or disease.

Beef imported from third countries requires much heavier public liability insurance premiums because of the increased risk of E.coli 0157 and other harmful bacteria.

Some South American beef production relies on the continued destruction of the equatorial rain forest and the use of GM soya which EU consumers can find distasteful.

Many third country imports fall short of EU welfare standards and carry the additional stigma of being price competitive as a result of the indefensibly low wages paid to peasant labour forces.

The environmental cost of delivering large quantities of beef over large distances is considered by many to be unjustifiable in food miles terms.

There is also avoidable uncertainty about cattle traceability, growth hormone guarantees and compliance with drug residue restrictions.

And the only product alternative within the EU is grass-fed, cross-bred steer and heifer beef from the Republic of Ireland because few UK consumers are prepared to do cartwheels at the prospect of Continental maize fed bull beef or cuts off heavy cows.

Importance of retaining SFP to improve production efficiency Despite these advantages retailers, caterers and burger specialists have still to acknowledge that an unavoidable result of decoupling and the elimination of direct support is the immediate need to retain supply security through significantly higher ex-farm prices. The NBA has calculated that it costs 300p to produce a carcase kilo of suckler beef in the UK, and in many instances it will cost more, but even though the average market price has jumped by about eight per cent to almost 195p since January 1st – there is still a gap of 105p between production cost and market income. The arithmetic surrounding dairy bred calves, which do not have to carry the cost of the cow, is only slightly less daunting. Beef crosses need at least 235p from the market and –O Holstein bulls need at least 215p but they are making anything between 160p and 175p depending on where they are sold. This chasm between cost of production and market income shows more than anything else the depth of the challenge forced on the industry by CAP reform. But many farms, almost all abattoirs, and even some supermarkets have still to work out what this means.

They have still to realise that coupled subsidy did nothing more than fill the gap and even with the help of all this money, in the most extreme examples it would have been £446 on a suckler bred steer if the £135 SCP on the cow is included. Some farms could still not pull together a net margin – even if family labour was not counted as a cost and chucked in for free.

Those of you familiar with the NBA will know that over the last nine months we have been saying the only solution to this problem is a 20-25 per cent cut in costs and a 25-30 per cent lift in prime cattle prices. If these became reality finishers would be taking something like 250p deadweight from the market and those that had cut their costs and become efficient would be enjoying genuine profit. We cannot see any other way out. It is absurd to think that if finishers continue to receive just 195p from the market they have any hope of surviving, or of being able to pay breeders a realistic price for store cattle and calves, by reducing costs from 300p to say 180p or less. And it is just as crazy to think that market prices have any chance of hitting 300p or more and leave farmers in a position where there is no need to react to decoupling because all their problems have been solved by a miraculous lift in sales income.

Nevertheless our formula, which is based on farmers, processors and retailers working to create a halfway house in which the industry's cost-income balancing problems are shared, is being attacked. The biggest opposition comes from slaughterers who hold out little hope of an early and substantial lift in the market and are praying, for their own – short term - survival's sake, that farmers will continue to underwrite their activity, as they did for decades with their coupled subsidies, and use their SFP to fill the gap between market price and cost of production.

The NBA response has been to advise farmers that the best chance they have of constructing a sound business is to ignore this pressure and use their SFP as a capital fund to finance the urgent changes they need to make. We have also told them that if they wish to continue with beef farming, they should introduce these changes as quickly as they can because they will never have more SFP at their disposal than they will this year or next - and the longer they put off biting the bullet the bigger their task will be and the less cash they will have to throw at it.

Just in case any of you are thinking that farmers using SFP to subsidise slaughterers, retailers and consumers, is a good idea let me spell out why it most certainly is not and why a fundamental realignment of retail beef prices is necessary if UK beef cattle production is to be preserved at levels necessary to maintain delivery of the consumer's preferred product.
These include:

SFP is a temporary payment designed to be used as a bridging mechanism to wean the beef sector off the coupled subsidy it has become dependent on.
The European Commission would like SFP to be used by farmers as a capital fund from which they draw down investment to make their business more cost effective and competitive so they can survive without it, or any other direct aid, after 2013.
SFP must in part be used by farmers to keep their farm in Good Agricultural and Environmental Condition as defined by UK governments which carries a yet to be determined cost.
SFP is subject to progressively large offtakes which include modulation to encourage improved environmental standards. In rough terms these may account for 10-12 per cent of SFP on an cross-UK basis from 2006.
SFP offtakes could rise by 7-9 per cent a year from 2007 if the European Commission does not solve the problems raised by its "One Per Cent Club" and is unable to balance its agricultural budget.
SFP is not index linked.

This almost certainly means that if producer requirement for SFP to re-model their businesses is not quickly recognised then UK production will fall dramatically – even though it is equally clear that UK beef is a high specification product that cannot be easily imported from elsewhere.

How production costs might be reduced

Producers must also play their part by identifying their real costs of production and working out exactly how savings can be made. There will be as many responses as there are farms but the easiest answers lie in their overheads. Exactly matching labour, machinery and other fixed costs with cattle numbers so they end up with the lowest possible unit cost of production will be their single biggest task.

It is noteworthy that around 40 per cent of overheads will stick irrespective of stock numbers – which is a powerful incentive against them being panicked into de-stocking without adjusting overheads and also emphasises that post-CAP expansion is a legitimate move in the right circumstances and the all round assumption that decoupling means production cuts on every farm is wrong.

The NBA thinks cost reductions of the magnitude outlined are possible if variables, as well overheads, are attacked. We would like to see SFP invested in better cow fertility management, better calf breeding and better feeding practices. There is convincing arithmetic to suggest significant savings can be made if each of these is tackled at the same time. But we are also certain that the farmers who are most likely to survive will have introduced imagination and entrepreneurship into their management plans.

For hill calf breeders this may mean bringing cows in later and fatter off grass, feeding less expensive silage over winter, and turning them out earlier, skinnier than they might have been, onto pastures that would otherwise have already been locked up for next winter's silage. Others may even contemplate, as long as they can overcome worries about disease spread and getting an autumn calving herd back in calf, contract wintering, along with other herds, on lowland cereal farms where cheaper grain, straw, silage and accommodation are available in bulk. If done successfully this could mean doubling the number of cattle on the farm over summer.

Some breeders could form partnerships with east coast finishers who use potatoes and other vegetable/root crop waste by arranging dual ownership, and dual income, from cattle sent for slaughter.

Young starters could take advantage of those older farmers who are clever enough to organise a regular income from SFP by releasing their land, at a nominal rent, to stock owners who contract to keep the land in GAEC.

Other negative rents are already being promised on farms prepared to undergo arable reversion this autumn and put down good leys so someone else's stock, and someone else's work can pull in the SFP.

Helpful market developments But cost cuts on their own are not enough so what can be done about price? If, as expected, cows born after July 1996 come back onto the market this autumn it will make the UK at least 80 per cent self sufficient and better able to defend itself against substantially discounted imports. After the manufacturing beef market has settled down the NBA expects properly finished cows to be selling for 140p-170p per dwkg (compared with 90p at present) and calf breeders to be turning well bred, younger cows out of their herds for substantially more than that in three to four years time – and then replacing them, to secure the high-price/high quality cycle, with beef-bred, non-Holstein, heifers.

Exports are expected to begin within a year, possibly by November, and this brings with it estimates that UK beef cattle values could rise by a further ten per cent – or 18-20p.

Conclusion Retailers and consumers hold the future of the UK beef industry in their hands and it is unfortunate that so far there are only limited signs of a positive market response.

UK ex-farm prices have risen by just eight per cent since January 1st and this is well short of the 30-35 per cent necessary to secure a viable beef industry – and that only if farmers themselves use their SFP to increase efficiencies and cut production costs by 20-25 per cent at the same time.

Will retailers respond in time – and can UK beef corner the quality niche on the EU market as well?

Eating Biodiversity: an investigation of the links between quality food production and biodiversity protection

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Introduction Modern UK ruminant livestock production is commonly based on ryegrass swards adapted to high fertilizer inputs. Coupled with the removal of hedges and ditches, these modern farming methods have resulted in a decline in plant and wild animal species diversity. Recent food scares, particularly in the meat industry, have led to a loss of consumer confidence and a desire for production to return to more traditional methods. 'Natural' food from an identifiable source is today perceived to be more 'trustworthy' than anonymous produce. Historical evidence has shown a variety of foods that drew their distinctiveness, both in taste and appearance, from the natural conditions of their production, including the biodiversity inherent in production sites (Tregear, 2003). It is notable, that following EU Regulation 2078/92, many agri-environmental schemes established in France were constituted around the production areas of distinctive food products such as cheeses, where the extensive grazing of species-rich and characteristic pastures ensures original and in some cases, highly sought-after products (Buller and Brives, 2000). Examples of grasslands with diverse botanical species, which may affect meat quality characteristics, are salt marsh, limestone uplands, heather mountain pastures and acid heath-land. There is some scientific but more anecdotal evidence that such pasture types introduce characteristics into meat and cheese, which improve various aspects of quality including flavour. This research project examines the relationships between biodiversity in pastures and the quality and value of foods produced from them. Positive relationships will provide economic opportunities for local and short food supply chains, as well as for the preservation of diversity.

Objectives of the research project

- To evaluate existing knowledge of the links between biodiversity and food products, and to gain information on management systems, final product quality and the impact on rural development;
- To assess the environmental, economic and social conditions outside the UK, for example France, where biodiversity and associated natural environmental traits are considered integral to food production;
- To examine existing food products, such as meat and cheese, and production practices in England and Wales which emphasise biodiversity as an important input to food production;
- To provide botanical and soil assessment of biodiverse pastures linked to scientific measurement of quality in 4 groups of beef animals, 3 groups of lamb, and 6 cheddar-style cheeses;
- To use a trained taste panel and consumer focus groups to determine the nature and perception of such products, and to compare them with control samples from a standard production system;
- To assess the actual and potential role of naturally embedded food products in rural development;
- To explore regulatory, contractual, and other means to deliver naturally embedded products;
- To identify effective management systems and examples of good practice for the integration of biodiversity as an element of product value.

The project is interdisciplinary in nature, involving social science, as well as plant and animal science. The research will investigate all of the key elements of entire food chains that emphasise biodiversity as an input. The findings of the social and natural scientific elements will be brought together and combined with a stakeholder input, to evaluate the overall operation of the food chains concerned.

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The effect of genotype and pelvic hanging technique on meat quality

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Introduction Currently 53 and 47% of prime beef production in Northern Ireland originates from beef and dairy herds, respectively. The beef herd comprises a diverse range of genotypes, which result in major variability in carcass weights, conformation and fat classification. The present study was undertaken to investigate the effect of genotype and pelvic hanging technique on meat quality.

Materials and methods The experiment involved a total of 41 steers, consisting of two breeds, Holstein (Hol) (initial weight range 409-639 kg) (100% Holstein) and Charolais (CH) (initial weight range 440-669 kg) (>75% Charolais). All animals were offered grass silage *ad libitum* supplemented with 4.5 kg concentrate for 98 days prior to slaughter. At slaughter, one side of each carcass was randomly allocated to one of two [BOTH pelvic?] hanging techniques, achilles tendon (AT) or tenderstretch (TS; carcass suspended through the aitch bone at 45 min post mortem until 48 hours post-mortem). Meat quality was assessed according to Lively *et al.* (2005). The design of the experiment was to produce cattle at a range of weights and the data were analysed using Genstat regression procedures with a model including the factor breed and hanging method and their interactions. The data was adjusted using covariates for age at slaughter and carcass weights.

Results and Discussion. There were no statistical significant differences in colour values (L*, a*, b*), nor in ultimate pH due to breed or hanging method (Table 1). Cooking loss was significantly higher in Charolais than Holstein, but hanging method had no effect on cooking loss. As expected, sarcomere length was increased ($p<0.01$) by tenderstretch hanging but was not significantly affected by breed. Warner-Bratzler shear force (WBSF) values were significantly lower in the tenderstretch-hung sides and, surprisingly, higher in Charolais than Holsteins(Table 1). The breed difference was much smaller in the tenderstretch hung sides than in the achilles hung sides, with the shear force values for Charolais sirloin being 1.5 times those of the Holstein sirloin when achilles hung (4.3 vs. 2.8 $kg.cm^{-2}$ respectively), but only 1.3 times greater when tenderstretch-hung (3.0 vs. 2.3 $kg.cm^{-2}$, respectively). These results clearly show the importance of hanging method to reduce differences in tenderness caused by breed. The results also show the importance of selecting the most appropriate post-slaughter procedures when studying the effects of breed on meat quality.

Table 1 Effect of hanging method and breed on meat quality of Charolais and Holstein Steers.

	Breed		Hanging Method					
	CH	HOL	AT	TS	sem	Breed	Hang	Int
L* (lightness)	36.3	34.9	36.6	34.4	1.90	ns	ns	ns
a* (redness)	15.6	18.3	17.3	17.1	0.75	ns	ns	ns
b* (yellowness)	12.3	14.7	13.9	13.5	0.71	ns	ns	ns
Ultimate pH	5.61	5.59	5.61	5.59	0.019	ns	ns	ns
Cooking loss (%)	32.8	27.9	30.1	29.7	0.45	***	ns	ns
WBSF ($kg.cm^{-2}$)	3.7	2.6	3.4	2.6	0.16	***	***	***
Sarcomere length (μm)	2.4	2.5	2.4	2.6	0.12	ns	***	ns

ns = not statistically significant ($p>0.05$); *** = $p<0.001$: WBSF = Warner-Bratzler Shear force; CH = Charolais; Hol = Holstein.; AT = achilles hung; TS = tenderstretch; Hang = hanging method; Int = interaction between breed & hanging method

Conclusions These results clearly show that the breed difference in tenderness in the sirloin, as measured by WBSF, is much greater in achilles hung than tenderstretch hung carcases. Thus when comparing production effects, we should use post slaughter conditions to optimise meat quality. It is also necessary to consider whether comparisons should be made on meat aged for different periods to reflect commercial practice. Further work is ongoing using consumer trials to study the effects of breed and hanging method on eating quality.

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Effect of carcass weight on meat quality of longissimus dorsi from young Holstein bulls

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Background In Northern Ireland, approximately 50% of beef animals slaughtered derive from the dairy herd while nearly 20% of animals are entire bulls. Previous research has studied the effect on the eating quality and other attributes of young bulls of diet and finishing, age at slaughter and genotype. However, little of this research has focused on young dairy animals.

Objectives This work aims to determine the effect of final live-weight of young dairy bulls on the eating quality of the beef from *the longissimus dorsi*

Materials and methods A total of 180 Holstein-Friesian bulls were blocked according to live weight and age, and allocated at random to one of 7 slaughter weight treatments. The target slaughter live weights for bulls were 300, 350, 400, 450, 500 and 550 kg, while a further group were slaughtered as steers at 450 kg. All animals were offered concentrates *ad libitum* and a restricted quantity of barley straw (nominally 0.5 kg/head/d). Fore rib joints and sirloins (*longissimus dorsi*) were removed from all animals at 3 days post slaughter. The longissimus dorsi from the fore rib joints was used for instrumental measures of meat quality taken at 7 days post slaughter. The full sirloins were, packed in a stored in vacuum bags at 2^0C for 21 days prior to sensory analysis. Following removal of fat and epimysium, samples were cooked to an internal temperature of 74 ºC in an electric fan assisted oven at 180ºC for an estimated cooking time of 30 minutes per 500g. Panellists scored samples for subjective attributes including acceptability of aroma, flavour, texture, and overall acceptability, and for objective attributes including intensity of aroma, intensity of flavour, tenderness and juiciness. Samples were also given a satisfaction score. Data were analysed by ANOVA, and all variates were tested for the presence of linear and asymptotic trends with carcase weight for the range of slaughter weights evaluated (bulls only).

Results and Discussion. A comparison of bulls and steers at the same slaughter weight gave no statistically significant differences for any of the instrumental measures of meat quality . The a* values (redness) increased with increasing carcase weight ($p<0.01$) and cooking loss showed a significant ($p<0.01$) decrease with carcase weight. There was a statistically significant asymptotic correlation with carcase weight for acceptability of aroma, ($p<0.05$), acceptability of texture ($p<0.001$) and tenderness ($p<0.05$). The asymptotic relationship between acceptability of texture and carcase weight explained only 17% of the total variation, indicating that predictions using this regression relationship would be unreliable. In the comparison of bulls and steers slaughtered at a similar live weight, the data showed that panellists considered *longissimus dorsi* from steers to have significantly ($P<0.05$) more acceptable aroma, flavour and overall acceptability. It should be noted that the acceptability scores for all attributes of the sirloin for bulls were high (> 64 at least). None of the intensity scores for aroma, flavour, tenderness, juiciness or satisfaction rating were significantly different between bulls and steers. The average satisfaction rating for bulls was 2.4, indicating a rating between "everyday quality" and "better than everyday quality". Farmer et al (2004) showed that the sensory quality of the biceps femoris muscle (silverside) from a subset of these animals (400 to 550 Kg live weight) depended on the location of the sample from within the muscle, such that samples from proximal portion were more acceptable than the centre portion of the muscle. Changes in sensory scores with carcase weight were more marked in the centre portion than the proximal portion of the biceps femoris (Farmer et al 2004). This illustrates possible problems when generalizing from meat quality results obtained from *longissimus dorsi* to other muscles within the carcase.

Table 1 Sensory analysis of roast *longissimus dorsi* (sirloin)

Slaughter weight	Sex Type	Acceptability Aroma	Acceptability Flavour	Acceptability Texture	Overall Acc	Intensity Aroma	Intensity Flavour	Intensity Tenderness	Intensity Juiciness	Satisfaction
450 kg	Bulls	68.5	64.5	65.3	65.5	51.3	50.2	62.9	56.5	2.4
450 kg	Steers	71.5	69.8	67.4	69.9	51.8	54.1	61.7	58.2	2.6
Statistical Significance	Sex[a]	*	*	ns	*	ns	ns	ns	ns	ns
	Lin[b]	ns	ns	ns	ns	ns	ns	ns	ns	ns
	As[c]	*	ns	***	ns	ns	ns	*	ns	ns

Significance of: a sex type; b linear fit with carcase weight;c asymptotic fit with carcase weight;
ns not statistically significant; *$p<0.05$; ** $p<0.01$; ***$p<0.001$

Conclusions Overall, the results showed that meat of acceptable quality could be obtained from Holstein bulls at relatively low slaughter weights. Comparison of bulls and steers at a slaughter weight of 450 Kg gave higher acceptability scores for aroma and flavour in steers, but objective sensory measurements were unchanged. Despite a highly significant asymptotic fit for acceptability of texture with carcase weight, this only explained 17% of the variation.

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