

Compression work study in order to set up an objective model of meat tenderness determination

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Several studies have tried to correlate shear forces with tenderness of meat determined by organoleptic methods. Nevertheless, this correlation is not sufficient to allow use of shear forces to predict sensory tenderness.

In our experience, two reasons explain this low correlation:

1. Shear force is only one aspect of the mastication phenomenon and its measurement gives only partial information (i.e. elasticity is not considered).
2. Maximum force is usually measured at a given time and cannot be compared to a lasting phenomenon.

The purpose of the present paper is to introduce the basic concepts of a new approach to the measurement of tenderness by another objective method. To improve the correlation we propose adding measurements of 1) compression work and 2) shear force.

Our study is based on the measurement of the energy needed for compression of a 70°C (centre) cooked meat sample of variable thickness. The novel aspect of the work is to use a constant force (40 kg) instead of a constant rate of compression to compress a sample of known diameter. The apparatus used was an INSTRON 1140.

All the recorded values (y) are plotted against the thickness (x) of the samples, for each type of meat studied (e.g. jarret, plate cuisse, aloyau, entrecote). One can draw a regression line ($y = ax + b$), and the correlation coefficient can be a good estimation of the homogeneity of the meat. If "a" is plotted against "b" in another two dimensional diagram, the different types of meat can be separated.

Structuro-mechanical characteristics of sausage and ham products with partial meat replacement

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Investigations were made with a universal test machine "Instron". To determine the value of the limit shear stress (LSS) of sausage meat the Instron traverse movement was limited, providing a constant depth of penetration of the conical indenter (with the 60° angle at the peak) into the samples. In this case, the LSS value was proportional to the force influencing the indenter; the indenter was fixed on the chart by the recorder. Cooked sausage meats with 25, 30 and 35% meat replacement by soy isolate or sodium caseinate or their mixture hydrated by cattle blood plasma were studied. To provide for coagulation structure formation, an aqueous solution of calcium chloride was added to the samples.

For investigation of the finished products the Instron was equipped with a "Warner-Bratzler" shear cell that allowed slicing of samples with the given section and determination of the value of the shear force. Structuro-mechanical characteristics of ham products in casings were studied with the help of a Kramer Shear Press cell that allowed estimation of the integral parameters for the objects with obviously expressed anisotropy of their properties.

It was found that the value of LSS increased with time for all samples including the control. The curves of dependence for $LSS = f(\tau)$ were S-shaped with the arbitrary "saturation" area at $\tau > 3600$ s.

The samples with 25% meat replacement differed slightly from the controls by the value of the shear force. The sausages with meat replacement by protein composition on the basis of soy isolate and blood plasma were closer to the control. With an increasing level of meat replacement the value of the shear force decreased still being, however, of an acceptable level.

The value of firmness and fragility were determined during the study of ham products with 20% semilean pork replacement of 3 types of "protein isolate-blood plasma" compositions and of the control sample. The numerical value of firmness was calculated by dividing the sample destruction force by the sample weight (N/kg).

The data obtained showed that the test ham samples were close to the control for firmness value and at the same time they were more "fragile" compared to the control. The combination of such characteristics provided for a tender consistency of the test ham samples.

The influence of milk and soy protein preparations on the physico-chemical and structuro-mechanical characteristics of freeze-dried ready-to-cook meats

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Physico-chemical and structuro-mechanical characteristics of freeze-dried meat minces and meals prepared therefrom have been studied in relation to the added levels of milk and soy protein concentrates. Structuro-mechanical properties were Instron-tested. The stickiness was judged by the tear-off force of the contacting materials; the limit shift stress was measured when applying tangential forces to minced meat by means of a conical nozzle; shear stress and penetration were determined with a Warner-Bratzler shear device and a metallic indenter (1/4 dm. dia).

It has been shown that at 30% addition of milk and soy proteins to the product there was a rise of pH-value from 5.76 to 5.96, of WHC by 4% and minced meat stickiness by 39%, and a reduction of the limit shift stress by 29%.

Shear stress and penetration values of the ready-to-eat meals were lower by 15 and 12% respectively and agreed with the organoleptic scores, and demonstrated that the addition of protein concentrates improved the product consistency.

Mechanical properties of fatty tissue

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The physical properties of fatty tissue, particularly its softness, affect its appearance, ease of cutting and slicing. Pork carcasses with excessively soft or oily fat are unsuitable for bacon manufacture. Most studies on softness of fatty tissue have been concerned with lipid chemistry rather than its mechanical properties.

Cylinders of pig backfat held at 3°C were compressed uniaxially to between 2 and 8% of their original height in 0.5 sec and the stress relaxation monitored for 300 sec. Plots of the stress against strain at given times after compression were non-linear, and stress increased progressively with strain when samples were compressed more than 3%, showing a progressive increase in stiffness with increasing compression. The equilibrium modulus varied from 3 to 80.10⁴ N/m² and its logarithm was linearly related to subjective firmness rating, assessed by the "thumb test".

Further evidence for the importance of components other than lipid is suggested by differences in mechanical properties between inner and outer lipid layers of backfat. The outer layer was 1.5 times harder than the inner but contained a greater proportion of unsaturated fatty acids and had a lower melting point.

Tensile strength of each layer was about 1MPa but, in the 'mature' collagen-rich fatty tissue beneath 'boar shield' it was about 10MPa.

Failure under tension of whole backfat, including skin, was initiated at much lower stresses (0.01MPa). Failure occurred by separation of sub-layers of fatty tissue adjacent to the boundary with *M. longissimus*.

The problems of the lack of cohesion and softness in fatty tissue of pig carcasses depend on the interaction of lipid and supporting cellular and connective tissues.

The fracture properties of cooked beef muscle

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The fracture behaviour of meat is of great relevance to its textural quality and to industrial processes involving size reduction of meat pieces. Previous work on meat fracture in relation to texture has tended to use empirical instrumental methods where complex looking patterns preclude a detailed analysis of events. In this study, an approach has been developed where quantitative measurements of basic fracture properties have been used to explain qualitative observations on the structural aspects of meat fracture, using the concepts of a fracture mechanics approach.

Simple tensile strips have been used to observe structural events in the fracture of meat cooked to 80°C. In all configurations studied, fracture started in the perimysial connective tissue, resulting initially in the separation of intact muscle fibre bundles. The ultimate tensile strength along and across the fibre direction was measured to be $\approx 300 \text{ kN m}^{-2}$ and 25 kN m^{-2} respectively. This anisotropy of tensile strength explains the ease with which fibre bundles can be separated in the cooked state.

Using the concepts of classical fracture mechanics, an energy-based measure of toughness can be defined as the work of fracture measured during the slow growth of a tear or crack. Work of fracture through the perimysium was measured to be in the region of 0.4-1.8 kJ m^{-2} , a value low in absolute terms, explaining why the perimysium is the preferred fracture site. The difficulty in propagating fracture across the muscle fibre direction was explained by the complete notch-insensitivity of the material, as measured by the linearly decreasing relationship between nominal breaking stress and the length of pre-cut notches across the width of meat samples.

These results suggest that meat cooked to 80°C may be modelled as a uniaxial fibrous composite of strong muscle fibres in a weak connective tissue "matrix", with poor interfacial strength.

Myofibril fragmentation index and sensory properties of pork and beef during post mortem storage

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Red meat is considered to be high quality food by most people. Tenderness is one of the most important qualitative properties. The tenderness of both beef and pork increases during post mortem storage. The ageing process results in changes in the myofibrillar structure; e.g. the myofibril fragments become shorter. The purpose of the study was to show the relation between sensory properties and myofibril fragmentation of red meat during post mortem storage.

The course of ageing of *M. longissimus dorsi* was studied by sensory evaluation (tenderness, chewing time, chewing residue, juiciness) and by myofibril fragmentation index (MFI).

The sensory evaluation was performed by a trained expert panel; MFI was measured as the absorbance of a myofibril suspension of a protein concentration of 0.5 mg/ml.

MFI was measured at the same time as the sensory evaluations were done at 24, 48, 96 and 168 hours post mortem. The bovine samples were also tested 240 hours post mortem. All samples were stored at +4°C.

Of the sensory properties the chewing time showed the best linear relationship to MFI for both beef ($r = -0.81$) and pork ($r = -0.50$). A better correlation was found for pork if chewing residue also was taken into consideration with multiple linear regression analysis ($r = 0.57$). Moreover, there were individual variations in the relationship between sensory properties and MFI. These variations can be due to meat quality of the carcass and to breed and sex of the slaughter animals.

MFI measurements are a valuable tool for studying the course of ageing in meat, but cannot be used as an absolute measure.

Effect of applying proteases on the tenderness of aged camel and buffalo meats

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Aged buffalo and camel meat (6-8 years old) were tenderized by different proteolytic enzymes from different sources, i.e. plant, microbial and animal. The enzymes were applied to the meat samples either singly or in combinations of two or three enzymes. The optimum units of each enzyme after determination were injected in the meat samples which were thereafter cooked at 100°C for 60 min. Different tenderness parameters were evaluated in the tenderized meat, i.e. T.S.P., F.A.N., tenderness and overall acceptability by panellists. The quality characteristics of tenderized meat samples differed according to the concentration (units) and type of enzyme used. A highly significant difference ($P < 0.01$) was found between the control (untreated samples) of both camel and buffalo meats and the samples treated with either a single enzyme, or two or three enzymes in combination. Using a mixture of two enzymes improved significantly ($P < 0.01$) the tenderness of either camel or buffalo meats compared with the affect of a single enzyme. A mixture of Rhozyme p-53 and pepsin was significantly ($P < 0.01$) better than the other two mixtures i.e. Rhozyme p-II and bromelin, and papain and trypsin.

Tenderization of meat with a mixture of three proteases did not significantly increase the tenderness scores. On the contrary, use of a single proteolytic enzyme improved significantly the tenderness of treated meat as much as a mixture of three enzymes.

Effect of anabolic agents on veal meat quality traits

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Veal meat from trenbolone acetate/oestradiol treated animals and controls has been compared by taste panel and biochemical measurements (fibre optic probe, myosin isoforms pattern, NMR measurements).

44 males from the Freisian breed, half of which were treated with oestradiol and trenbolone acetate (50 days before slaughter) were slaughtered at approximately 140 days. The average carcass weight was 120 kg.

After cooking to an internal temperature of 80°C, the Longissimus dorsi muscle was tested by trained taste panel for tenderness, juiciness and flavour intensity. The results show significant differences: scores, on a ten point scale, were always lower for the experimental animals. The mean difference is - 0.9 point for tenderness ($P < 0.001$), - 0.4 point for juiciness ($P < 0.001$) and - 0.3 point for flavour intensity ($P < 0.05$).

No differences were recorded for cooking losses.

Regarding muscle characteristics, we did not observe any difference in the ultimate pH between experimental and control animals.

The Longissimus dorsi muscles of the experimental animals exhibited:

- a higher degree of protein denaturation assessed by fibre optic probe measurements
- a significantly different pattern of myosin isoforms with a higher percentage of the slower forms (isozymes IV and V) and a lower percentage of the fast isozyme I.
- a significant difference in the water proton relaxation times T_1 and T_2 : the T_1 and T_2 of treated animals are lower than those of the controls although no significant difference appears in the total water content of muscles of both groups.

Differences mainly in texture induced by the anabolic treatment are easily detected by a taste panel. These differences are tentatively related to changes in protein composition and water mobility.

Volatile compounds arising from the reaction of sodium nitrite with pork during curing

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The characteristic flavour of cooked meats is attributed to the use of sodium nitrite in curing and this has been clearly demonstrated in several studies on the sensory properties of pork products prepared with and without sodium nitrite. However, the chemistry of cured flavour has received much less attention. In this study the flavour volatiles from pork products containing different amounts of sodium nitrite were compared with volatiles from nitrite-free salt pork and untreated pork.

Cured pork was prepared by either a slice cure method or by mixing comminuted meat with curing salts, to give products in each case containing approximately 200 and 1000 ppm sodium nitrite. The products were boiled and the volatiles were extracted by continuous steam distillation - solvent extraction in a Likens-Nickerson apparatus. Some samples of slice-cured bacon were also fried before volatile extraction. The volatile extracts were then analysed by combined gas chromatography - mass spectrometry.

In addition to the well known classes of compounds (aldehydes, alcohols, etc) a number of novel nitrogen-containing compounds were found in the cured meats which were absent from the nitrite-free samples. These included a number of alkanenitriles, benzonitrile, phenylacetone nitrile and several alkyl nitrates. The meats cured with the high level of sodium nitrite contained considerably more of these nitriles than the lower nitrite samples, and the fried sample from the high-nitrite slice-cure contained over 700 ppm heptanenitrile. These nitrates and nitriles appear to derive from the interaction of sodium nitrite with lipid or lipid oxidation products. Although these compounds did not appear to have odours suggestive of cured meat aroma, the reactions involved may indicate possible new mechanisms involved in the formation of the actual character impact compounds associated with flavour in cooked cured meats.

Influence of electrical stimulation and slow chilling on texture of turkey breast muscle

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Turkey carcasses are normally spin chilled about 20 minutes after stunning and reach about 7° in a further 45 minutes. After holding overnight at 0° carcasses are frozen. Under these conditions toughness could result from cold shortening, and normal ageing would not occur.

Using 8-9 lb birds, slaughtered conventionally, comparisons were made of:

- non-stimulated and low voltage electrical stimulation (95V applied for 30 seconds prior to bleeding)
- X normal spin chilling and slower air cooling for 24 hours at 1° to 5°.
- X and unaged (i.e. cooked immediately after thawing) and meat thawed and aged for 7 days at 1° prior to cooking.

Toughness was measured instrumentally on *M. pectoralis thoracicus*.

Twenty minutes after slaughter the pH of non-stimulated muscles varied from 6.2 to 6.8 and averaged 6.43. In electrically stimulated carcasses pH varied from 5.3 to 6.3 and averaged 6.06. The ultimate pH averaged 5.74 and was similar in all treatment groups.

Toughness values ranged from 1.7 to 5.0 and averaged 2.8 kgf. Air chilling decreased toughness (from an average of 3.0 in control to 2.5 kgf). Of the sixteen toughest muscles (from the total of 126 examined) 14 were in the group which had been spin chilled.

Ageing decreased toughness slightly from 2.9 kgf in unaged, to 2.5 kgf in aged muscles.

Electrical stimulation did not significantly affect toughness values overall.

Toughness was related to pH at 20 minutes. Slow glycolysing muscles, in which the pH was still as high as 6.8 20 minutes after stunning, were toughened most under normal chilling. Faster glycolysing muscles, with pH 6.1 to 6.5 after 20 minutes, were tender and not cold-shortened by normal chilling. Those very fast glycolysing muscles, with pH as low as 5.7, 20 minutes after stunning and which came from stimulated carcasses, also could be tough, particularly when subjected to spin chilling.

Consumer acceptance of Wiener sausages

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A consumer study was made at the Veterinary and Agricultural University of the acceptability of two Vienna sausages with marked quality differences due to the choice of meat ingredients. One was made of pork while the other contained mechanically separated chicken meat as sole meat ingredient. A total of 1075 persons participated in the study which was divided over a three day period. During Saturday and Sunday the panel predominantly consisted of guests from the town, while the Monday panel predominantly consisted of students. On Saturday and Sunday 30 percent preferred the "chicken sausage", 62 percent the pork sausage, whereas 8 percent expressed no preference. On Monday the sausages were served with mustard and tomato ketchup. Now 37 percent of the participants preferred the "chicken sausage", 52 percent the pork sausage, and 11 percent had no preference. The results suggest that condiments disguise quality differences which consumers clearly perceive when bare sausages are served.

The influence of acetic acid concentration on the efficiency of marinading as a process for tenderizing beef

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Marinading has traditionally been used in culinary circles to flavour and tenderize meat. The active tenderizing ingredients are thought to be the organic acids found in typical marinading solutions such as vinegar, wine or fruit juice. The aim of this work was to investigate how beef tenderness could be influenced by varying the concentration of acetic acid used in marinading solutions.

M. longissimus lumborum muscles from four young steers were obtained commercially three days after slaughter and cut into steaks approximately 1.0 cm thick from which discs of meat 3.0 cm in diameter (weight 7.5 ± 1.0 g) were prepared. Acetic acid solutions in the range 0.01 N to 3.00 N were used as marinades. Meat discs were individually marinated in 50 ml acetic acid solution for 48 h at 4°C with continuous swirling at 120 rpm. Each marinading treatment was replicated four times for each animal. Meat discs were then reweighed and two from each treatment analysed for pH, titratable acidity and total nitrogen. The remaining two were assessed for tenderness after cooking for 20 min at 80°C. All marinading solutions were analysed for pH, titratable acidity and total nitrogen.

Meat discs gained up to 100 percent of their raw weight during marinading, maximum swelling occurring in the range 1.00 N to 1.50 N acetic acid. These samples had shear values of around 0.30 kg cm^{-2} compared to control values of around 5.00 kg cm^{-2} . Marinading in much weaker 0.10 N acetic acid caused a 50 percent weight increase with corresponding shear values less than 1.00 kg cm^{-2} . Approximately 12 percent of the marinading acid was absorbed by the meat throughout the concentration range studied, giving meat discs a pH range from 4.0 to 3.0. As much as 25 percent of the total nitrogen content of the meat was found in the weaker marinading solutions which decreased to 14 percent at higher acid concentrations.

It is concluded that the acid concentration of marinading solutions has a marked effect on beef tenderness. This was strongly related to an increased hydration of the structural components of beef which was substantially retained during cooking.

Some factors affecting the toughness of pork

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Samples of the *M. longissimus dorsi* (LD), mean weight 112 g, from boars and gilts, mean cold carcass weight 55.3 kg, mean P2 fat depth 15.0 mm, were cooked at 80°C for an hour and sheared on a Warner-Bratzler shear device. Simple correlations between both Warner-Bratzler initial yield force (IY) and peak shear force (PF) values and carcass weight, P2 fat depth, LD ultimate pH, meat colour score, LD sarcomere length and weight loss during cooking were calculated. Shear values increased as LD ultimate pH decreased, $r = 0.60$ (IY) and 0.63 (PF), as meat colour became paler, $r = 0.40$ (IY) and 0.42 (PF), and as cooking loss increased, $r = 0.62$ (IY) and 0.66 (PF).

We consider that cooked meat with a Warner-Bratzler IY value of 8 kg or more is likely to be considered tough by consumers. 22% of the samples had IY values of 8 kg or more! Samples from boars had lesser IY values ($5.4 \bar{y}$, 6.7 kg , $P < 0.05$), greater LD ultimate pH values ($5.95 \bar{y}$, 5.61 , $P < 0.05$) and were darker (colour score $3.6 \bar{y}$, 2.8 , $P < 0.05$) than those from gilts. Sex differences in colour and shear values were pH related. It was concluded that pale pigmeat is likely to be tough.

Relationship between fat content and sensory scores for palatability of beef

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Fat content of beef has become of increasing concern to Canadian consumers as a result of health implications raised by recent studies, whereas the contribution of fat to the palatability of Canadian beef remains unclear. This study examined the relationship between fat content and sensory scores for tenderness, juiciness and flavour, and between fat content and cooking losses.

Longissimus dorsi (LD) and semitendinosus (ST) roasts obtained from 179 animals from three trials were evaluated by eight member trained panels using an unstructured scale and intensity anchor points for tenderness, juiciness and flavour. Animals were scanned ultrasonically and slaughtered over a wide range of fatness (0 - 15 mm fat thickness at 11/12 ribs). Effects of grade and marbling were determined using analysis of variance. Relationships between fat content and sensory scores and cooking losses were examined using the partial correlation technique. Fat content was examined as carcass fat (physically separated adipose tissue), roast fat (lipid content of whole commercially trimmed roast), and muscle fat (lipid content of the muscle tissue). Both roast fat and muscle fat were determined on cooked meat.

Although analysis of variance and Kramer's-Tukey test showed a significant difference ($P < 0.05$) between Grade A and Grade C animals and between high and low marbling scores for carcass fat, roast fat and muscle fat, no significant correlations were obtained between carcass fat and either roast or muscle fat. Significant differences ($P < 0.05$) between Grades A and Grades C for flavour scores and between high and low marbling scores for flavour scores were obtained for LD roasts but not for ST roasts. Positive correlations ($P < 0.01$) were obtained between carcass fat and flavour scores for LD roasts but not for ST roasts. No significant correlations were obtained between flavour scores and either muscle fat or roast fat. Effects of fat content, grade and marbling scores on panel scores for tenderness and juiciness were not consistent and less than for flavour. Muscle fat was more related to total cooking losses ($P < 0.05$) than either carcass fat (N.S.) or roast fat (N.S.). Roast fat was more related to dripping losses ($P < 0.001$) than muscle fat ($P < 0.05$) and carcass fat (N.S.).

This work suggests that carcass fat may play a role in determining flavour of high fat cuts such as the rib. Muscle fat and roast fat appear to have greater effects on cooking losses but less on flavour. Effects of fat content of the trimmed roasts on cooking losses and moisture content were not reflected in panel scores for juiciness or tenderness.

Consumer acceptance of processed pig meat in relation to the composition of the fat

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Various processing treatments were applied to meat from boars, gilts and castrates reared under different feeding systems designed to change the fat composition and fatty acid content at light (95 kg) or heavy (115 kg) slaughter-weights.

Consumer tasting of cooked "Paris" ham, dry sausages, or dry salted ham gave sensory assessments on each product (N = 721 to 1 312) with comments on flavour, taste and overall acceptance largely related to the basic properties of the raw meat. The mean levels of intra-muscular fats (1.5 to 2.3%) unsaturated fatty acid levels of backfat (64 to 73 as index), and sex-related fat soluble substances (<0.5 to >1.0 ppm of androstenone) were on the whole the factors limiting the acceptance of the products.

- The higher fatty acid unsaturation level was less favourable towards good flavour development in dry salted ham, particularly because of the long drying process.
- The higher slaughter weight improved the overall acceptance, especially for flavour in the cooked hams and the dry salted hams.
- The negative effect of higher androstenone content was more marked as the limiting factor in flavour and general acceptance in the cooked hams than in the dry sausages.

Consumer acceptance may be improved by correction of some of the defects in the fats by various processing treatments.

Quality of cull cow beef

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It is estimated that 350,000 cull cows are slaughtered in Ireland yearly. Most culling occurs in Autumn and Spring when cows are in poor condition. Carcase weights from cull cows are low (average 217kg.) with potential for increasing weight. Carcase value for cull cow beef is lower than that for normal beef.

After culling, cows were divided into two groups of 22 each, one group was slaughtered immediately and the second group was pasture fed for three months prior to slaughter. The aim of the study was to evaluate differences in quality and profitability between the two groups.

Weight Gain: Cows with larger frames and those with poor initial condition showed greatest liveweight gain (up to 2 lbs per day) during the feeding period. In the carcase, the topside/silverside from the round and the chuck/shoulder from the forequarter showed significantly greater increases in weight than the remaining cuts.

Colour - Flavour - Juiciness: A judging panel found no significant differences in colour, flavour and juiciness between the two groups. Older animals scored less for both groups.

Tenderness: Taste panel scores indicated significant differences in tenderness between the good quality and poor quality carcasses within the first group. However, there were no significant differences between groups. Mechanical tenderisation resulted in significant increases in tenderness in all cases and increased cooking losses. Instron shear value measurement was used to confirm taste panel results.

In summary, cull cows in poor condition and having a larger frame, fed on pasture, show substantial weight gains which can be of good quality.

Comparison of meat quality in steers and young bulls at different live weights and feed levels

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During the last 20 years extensive studies of growth, feed efficiency, carcass characteristics and meat quality in relation to beef production under Danish conditions have been carried out in close cooperation between the National Institute of Animal Science and the Danish Meat Research Institute. The objective of one of these studies has been to compare beef production in steers and young bulls. The experiment was designed as a 2*4*4 factorial experiment including two sexes (steers and young bulls), four live weights (425 kg, 550 kg, 675 kg and 800 kg (bulls only)) and four feeding levels. This paper describes the meat quality results from the study.

A total of 120 Danish Friesian (SDM) calves from three sires were included in the experiment, starting at 73 days of age. Castration was performed at approximately 3 1/2 months of age. Steers and bulls were fed alike according to weight with mainly concentrates and fodder beets. All animals were slaughtered and evaluated according to the Institute's standard procedures. The determination of meat quality included ultimate pH, Elrepho reflectance (R₅₃₅), chemical composition, pigment content and shear force measurements on Longissimus dorsi (LD), as well as taste panel evaluation of Longissimus dorsi prepared as steaks and Semitendinosus (ST) prepared as roastbeef.

The main results were as follows:

The intramuscular fat content in LD was considerably higher in steers (4.33%) than in bulls (1.84%). In steers the fat content increased faster with increasing slaughter weight than in bulls.

The pigment content was slightly higher in steers (159 ppm) compared with bulls (148 ppm). The pigment content increased for both sexes with approx. 30 ppm per 100 kg increase in live weight. For young bulls the influence of feeding level on pigment content was minimal.

Longissimus dorsi from steers had a lower shear force value (7.2 kg) than LD from bulls (9.7 kg). Ageing until two to three weeks post mortem reduced the difference.

Taste panel evaluation showed that the tenderness and flavour were better and less variable in LD from steers than in LD from bulls. With increasing slaughter weight the tenderness in LD was unchanged or slightly reduced, while the tenderness in roastbeef of ST was markedly reduced in bulls and only showed small changes in steers.

These results are in accordance with previous experiments, and show that the difference between steers and bulls depends on the age, weight and feeding level at which the comparison has taken place.

Experience in taste testing fresh pork at the Danish Meat Research Institute

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Nowadays instrumental and analytical methods are often used in research work, but when organoleptic characteristics are to be described or assessed in detail, a sensory method is indispensable because a sensory evaluation gives results that cannot adequately be determined by physical or chemical tests. At the Danish Meat Research Institute methods have been developed for assessing the eating quality of pork. This paper describes experience in taste testing pork chops.

Details of the chosen procedures including sampling, ageing and preparation are given, as well as the composition of the taste panel and the scoring scale. Moreover, the procedure for testing the suitability of panel members for taste testing is described.

Finally the paper gives some examples of the practical application of taste testing work at the Danish Meat Research Institute. In this work clear effects of WHC and intramuscular fat have been found on taste characteristics of pork chops. With low intramuscular fat levels PSE-meat is tougher than normal meat (experiment 1). In meat with good WHC, high intramuscular fat contents ensure a better eating quality (flavour, tenderness and juiciness) than low intramuscular fat contents (experiment 2).

	Experiment 1		Experiment 2		
	PSE	normal	Low fat	medium fat	high fat
Flavour score	0.9	1.7	0.8	1.7	2.2
Tenderness score	-0.7	1.7	1.3	3.1	2.4
Juiciness score	1.1	2.0	1.7	3.2	2.5

Feeding experiments have shown decreasing flavour scores for pigs fed with increasing amounts of animal fat ranging from 0 to 30 percent of the total energy content of the feed.

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Certification of the level of quality of meat and meat products: interest and limits of the French grading system called "label rouge agricole"

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Except for the definition of hygienic standards for whole meat and meat products, and the determination of compositional standards for some processed meats, there is no regulation in France to fix and guarantee quality categories for different types of meat and meat products. This is unfortunate given the importance of these products in the food costs of consumers. Various solutions may be suggested to remedy this situation. The present paper describes the characteristics, the interest and the limits of the so-called "label rouge agricole" system used, in France, to assess levels of quality in food products. In this system, the products coming from organized producers having a sufficient level of quality are marked with a red label, showing a common stamp authorized by the Ministry of Agriculture. The only producers to benefit from this labelling are those officially authorized on the recommendation of the National Commission, which includes experts from every scientific and technical area and including consumers' representatives who judge the feasibility of the contracts taken by the producers to guarantee the quality levels. The regular control of the producers is enforced by a private certifying organisation which is independent of both the Administration and the producers, and frequently reports back to the National Commission.

Since 1965, the system has been used for different agricultural products although mainly for a variety of meat products: fowl (chicken, turkey, ducks, guinea fowl), veal, beef, cooked ham, dry ham, dry sausages, rillettes and pies. The level of quality is guaranteed in different ways according to the product. For processed meat, analytical data concerning the compositional standards are of primary importance but also guidelines are given for strict definitions of raw material and of the main steps in processing (e.g. cooking temperature, drying time). For meat, the conditions of production are most important (e.g. strain, age at slaughter, type of feeding in the case of chicken; age, type of suckling, carcass characteristics-conformation, fatness and meat colour, in the case of veal carcasses). Special recommendations are also given for veal and beef to avoid cold shortening conditions during post mortem chilling of carcasses. At the moment, the products sold with the red label compete reasonably well with the same types of "unlabelled" products considering their level of quality or their relative importance on the market: for chicken, about 10% of the whole production is labelled, and for processed meats, in percentage terms of the industrial production, about 5 to 6% for cooked ham, and 3 to 4% for dry products and other processed meats. The system of "label rouge" coexists with other systems and methods to guarantee quality which are defined either by the profession (code of the professional practices) or even by private registered firms.

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Changes in meat tenderness during storage

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Meat tenderness is one of the most important quality indices. The data on changes in the elastic modulus of vacuum-packed meat stored both subcooled and subfrozen are presented in the paper. Reliable data on the elastic modulus were obtained by applying the load of $P = 0.118 \text{ N/m}^2$, time of application being 30 s. The rigidity of the meat was observed to reduce during storage at subcryoscopic temperatures. Analysis of the data on the changes in the elasticity modulus proved the favourable effect of the packing on the tenderness of the meat.

Rheological behaviour of meat in compression at different strains and strain-rates

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The rheological properties of meat have been studied in order to improve conditions for the instrumental evaluation of tenderness. A machine, producing sinusoidal compression was devised at the Meat Research Laboratory of I.N.R.A. to study the rheological properties of raw meat. Several tender and tough muscles have been analysed at frequencies of 0.1 and 10Hz with strains ranging from 0.2 to 0.9. The direction of compression was perpendicular to the direction of the muscle fibre. Two parameters, (a) the maximum stress (resistance) reached during a cycle and (b) the elasticity factor, have been used to characterize the rheological behaviour of the samples.

At strains less than 0.2, all the muscles, except the Psoas major, give similar values for maximum stress and elasticity. Increasing the strain from 0.2 to 0.5 caused a rapid increase in both maximum stress and elasticity factor. For higher strains, muscles show various resistances according to their amount of connective tissue while the elasticity factor decreases rapidly. The Psoas major showed all these phenomena but at lower strains. For all the muscles, the strain rate had very little influence on the value of these parameters.

As the muscles cannot be differentiated at low strain values, the connective tissue does not contribute to this strain range, an important role in the rheological behaviour. The resistance and elasticity of this component can only be detected when the strain is greater than 0.3. At strains higher than 0.5 the breaking of the samples induces a decrease in elasticity and limits the increase of stress. For the Psoas major, which is stretched on the carcass, the connective network acts even at low strains, producing high maximum stress and elasticity.

A further study has shown that the maximum stress and the elasticity factor, measured at a strain of 0.2, refer to the myofibrillar component as these parameters vary over a large range during the onset of rigor mortis and further on during ageing. Moreover electrical stimulation greatly influenced these parameters.

The very low effect of strain rate on the rheological behaviour shows that, although the muscular tissue is visco-elastic, it is mostly elastic. We have found that this behaviour can be described by a Kelvin-Voigt model in which the modulus of the elastic component is a function of the strain.

A new testing device to study the rheological properties of meat

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Rheological studies have not yet afforded a completely satisfactory evaluation of meat tenderness. Two main reasons have been put forward (i) during the tests performed with most of the machines devised for meat texture evaluation, the strain conditions are not very well defined and controlled and (ii) the strain rates are very low compared with those involved in the mouth during mastication. Most solid foods are strain rate sensitive which means that the rheological parameters depend on the speed at which the test is performed. Mastication involves compression speeds from 0 up to 20 cm/s depending not only on the textural characteristics of foods but also on the individual variations. But most commercial systems manufactured for food texture evaluation do not allow tests to be carried out at speeds higher than 2.5 cm/s.

The apparatus which has been devised produces a rectilinear sinusoidal compression. The sample height can vary from 3 to 30 mm. One or several compression cycles can be carried out on each sample, the delay between the cycles can be varied from 1 to 10 seconds. The compression ratio can be selected between 0.1 and 0.95 whatever the sample height in the previous indicated range. The time necessary to perform one compression cycle can vary from 0.1 s to 20 s which allows overlap of the deformation rates reached during mastication.

Force values are obtained from a quartz transducer. One hundred data are collected during each cycle whatever the compression rate, the sample height or the compression frequency. The data are transferred directly to a computer which draws the stress-strain and stress-strain rate curves and calculates the following rheological parameters: maximum stress, strain at maximum stress, and the elasticity factor which is the ratio of the energy restored by the sample to the energy provided by the system during the down motion of the probe.

This device has been used to test rheological models and raw meat. Investigations are now being carried out on cooked meat and on various meat products.

Increase of profitability in the meat industry by means of quality cost analysis

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Slaughterhouses and meat processing plants using the present control systems do not produce faultless products; neither are the existing accounting systems structured in such a way as to clearly show the costs of poor quality and the opportunities of increasing profitability by reducing wastage and improving quality. This paper deals with quality costs in slaughterhouses and meat processing plants. The results come from two different investigations and the purpose of the studies was to estimate quality costs within the meat industry.

Quality costs are defined as:

Prevention costs: Costs for actions aimed at minimizing appraisal costs, internal failure costs and external failure costs.

Appraisal costs: Costs for supervision and inspection.

Internal failure costs: Costs which arise when defective products are produced and detected before delivery.

External failure costs: Costs which arise when defective products are delivered to customers outside the company.

Quality costs can be estimated in two ways. Either by a "one shot" study or by collecting results continuously. Both methods were used. In the slaughterhouse the one shot method was used, and in the meat processing plants results were collected continuously.

When initiating the identification and valuation of quality costs one soon finds that the accountancy methods are of very little help. Sources that have been used to identify quality costs have therefore been: quality control programmes, temporary records and statistics.

The estimates in this study are based on data from the meat industry. Occasionally, it has not been possible to do an estimation of certain types of quality costs with reasonable accuracy; on these occasions estimates have not been made. That means that in reality the costs are even higher than those shown in this study.

We have come to the conclusion that poor quality can cost:

In slaughterhouses (slaughtered kg) £0.02 /kg

In meat processing plants (manufactured kg) £0.07 /kg

Reducing quality costs to zero is not feasible, but a reduction of 50% can increase profitability considerably. Experience from other types of industries shows that reducing quality costs is one of the easiest and fastest ways of increasing profits.

Our results show that quality cost analysis is a field that is well worth further development within the meat industry.

Dimensions of flavour perception between normal and DFD beef

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The aim of the experiment reported here was to determine whether pH differences between normal ultimate pH (pHu 5.8) and dark-cutting beef (pHu 6.2) were reflected in subjective estimates of flavour difference among 7 treatments. Differences in pH were tested independently of concomitant variation in muscle composition by chemically adjusting the pH of normal beef to 6.2 and DFD beef to 5.8, either before or after cooking. To eliminate any interference of texture or appearance on the flavour assessments, aqueous extracts, produced from cooked homogenised treatments, were tasted from darkened glass containers using drinking straws.

The need for a descriptive vocabulary for beef flavour was also eliminated by requesting assessors to score paired samples for flavour difference. The data was analysed by an Individual Differences Scaling program, INDSCAL, which maps the differences among treatments as distances in multidimensional space, according to the consensus of assessors scores. The dimensions of the space are interpreted in terms of information known about the experimental treatments.

One unique aspect of an INDSCAL analysis is that individual variation in perception of sample differences is accounted for and built into the model. The basic hypothesis is that an individual will vary in the relative weighting they give to the dimensions in constructing an overall difference score. Indeed, an individual may not perceive a dimension at all (zero weight) or may vary from replicate to replicate if his attention is shifted from one dimension to another.

Three dimensions of flavour difference were recovered by an INDSCAL analysis of the beef samples. The first dimension indicated that making pH adjustments before cooking produced a larger flavour difference than a corresponding treatment adjusted to the same pH prior to tasting. This dimension was interpreted as a combination of pH and titratable acidity. The second dimension separated samples that were originally DFD from those that were originally normal pH. This indicated the presence of a flavour difference between normal and DFD beef independent of pH. The chemicals added to adjust pH contributed a third dimension.

Substantial assessor variation was observed in the INDSCAL weights calculated for the three flavour dimensions. No assessor detected more than two dimensions during a replicate and there was evidence of switches in attention from one dimension to another by some assessors.