

EATING QUALITY OF MEAT - THE INTERACTION OF COMPOSITION, PREFERENCE, REGULATION AND MARKETING

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In this, the introductory paper of the opening session of the 22nd Meat Research Congress, I hope to demonstrate that eating quality is the most important property of meat from the point of view of the customer and, therefore, of the industry; to discuss how eating quality can best be measured and what such measurements mean in relation to the consumers' preferences. In addition, since national and international legislative bodies are continually intensifying their control of the supply of food both within and between countries I will also discuss the possibility of establishing standards of eating quality in meat meaningful in either context. These interactions are summarised in Table 1.

Meat as a component of the diet

The housewife in all developed countries, at least, spends more of her food budget on meat than on any other food and the proportion remains almost unchanged even despite relative increases in price. Why is it so popular? Meat provides a major source of first class protein and, within the limits of the amount of fat eaten, it can be a major source of calories. It cannot be classed, however, as the major source of any vitamin and, in diets such as those now current in the USA, the United Kingdom and many other countries, the removal of meat entirely from the diet would not reduce the intake of any essential nutrient below the usually accepted daily requirement. Such statistics are of course suspect because they deal with average values and many particular groups within populations might well be on risk if any one food were withdrawn completely. It must be added, too, that the consumption of the saturated fats typified by those in meat from ruminant animals is now thoroughly contra-indicated on the evidence of the aetiology of heart and circulatory diseases. It is, however, quite unprofitable to look for the causes of population behaviour amongst such factors based on reason, nutrition or prophylaxis as is adequately demonstrated by the world wide rejection by smokers of cancer warnings.

The positive factor which causes people to eat meat is because they like to eat it : the consumption of a carcass of other animals appears in some way to give a unique eating satisfaction to human beings not obtained from any other foodstuff. Possibly this is rooted in a dim consciousness of our primeval hunting and carnivorous behaviour in the ages before the domestication of animals. Red meat is almost universally liked in meat-eating cultures and, when introduced into fish-eating cultures, meat is rapidly accepted and becomes the staple wet protein food within the price structure; to Europeans, quite astonishing amount of meat are eaten in producing countries such as Argentina and Australia. The objectives of the supplying industry, of research supporting it and of regulations governing it should, therefore, have as the major aim the increase of the supply or the reduction of the cost while maintaining or improving the eating quality. In much research

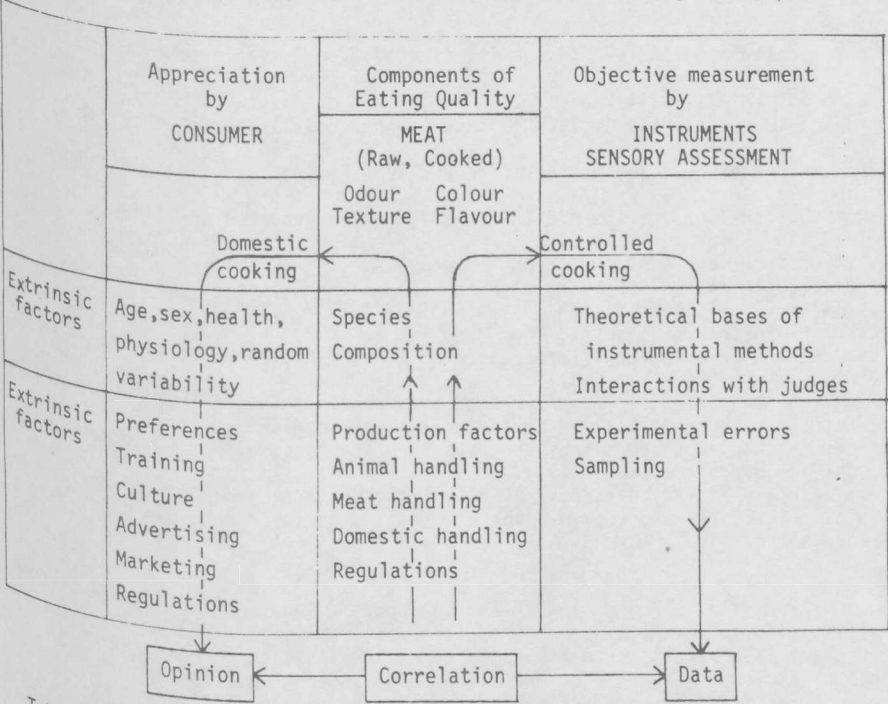


Table 1. Sources of variability in the quality of meat and in methods of assessing it by measurement or by consumers.

and development in the past eating quality has been ignored while considerable improvements in output or economics have been achieved by developments in agriculture, breeding and technology. Among the reasons for this are that meat science has not described comprehensive and accurate methods of assessing quality, that the methods are expensive and tedious and that, in general, the production experiments are carried out in units remote from food science both in location and in philosophy. In recent years coordination has improved and

meat research workers should be thinking in terms of correlating all types of study from breeding to cooking with the ultimate aim which is eating quality.

Measurement of eating quality

The extrinsic factors which can affect meat quality appear in the lower centre of Table 1 and their effects are mediated through the composition of the meat within each species. Since the eating quality of the cooked meat is a result of the physical and chemical reactions brought about by the heating process used in cooking, in theory an analysis of the substances present in raw meat should be adequate to predict the eating quality of the cooked. However, the odour and flavour of cooked meat are known to be the result of the presence of at least 180 volatile compounds in the aroma. The texture of cooked meat results from a combination of the increase in mechanical strength as the weak gel of contractile and sarcoplasmic proteins denature into an insoluble precipitate losing water and becoming fibrous, with a decrease in the strength of the connective tissue collagen as its denaturation firstly destroys the tertiary structure and then produces a gel or even a soluble monomer. In view of the complexity of these reactions no analysis of the raw product can be expected to predict with any degree of certainty the eating qualities of the cooked.

The MRI standard method for beef

We have devised at the MRI a series of measurements on both raw and cooked beef, which I would like to describe briefly in order to illustrate the difficulties in arriving at an adequate description of the meat from a beef animal. The procedure is summarized in Table 2, and the scales used for sensory assessment in Table 3.

The choice of joint was restricted to one joint and one method of cooking because the amount of work necessary to make an adequate examination is so great that more than one joint becomes impossible. The expensive loin joint was chosen because roasting is a simple and controllable method of cooking in common use in England and it produces both lean and fat in a single slice. We believe too that eating quality is of importance to the consumer and the industry only in the expensive meat - it is of less consequence in stewing and casserole uses. Roasting of a large joint is preferred to grilling or frying smaller pieces because the heating is more controllable and the variability in time/temperature treatment is less. In comparative tests we have shown that the variability in the assessment of the roast joint is about one half of that when grilled *gluteus medius* muscle was judged. The 15 cm rolled joint allows us to discard the outer 5 cm layer which has had comparatively uneven time/temperature treatment and to supply the taste panel with the fairly homogeneously cooked *longissimus dorsi* muscle only.

Fatness estimation is based on relative areas of meat and fat in the cross-section at the 10/11 rib and 3/4 lumbar vertebra. The measurement correlates well with whole body fatness levels.

Chemical analyses include water, fat, protein; and hydroxyproline, pH and total pigment of the lean and yellow pigment in the fat.

Colour measurements are made with a Hunter reflectance meter in comparison with a standard tile and the same

Table 2. The MRI standard procedure for describing the eating quality of beef from a single carcass.

1. pH_F measured by probe electrode in l.dorsi at 10/11 rib.
2. Standard cut from 10/11 rib to 3/4 lumbar vertebrae including flank taken 7 days after slaughter at 1°C or commercial chill.
3. Cut faces trimmed and traced onto polyethylene film, photographed and lean and fat areas determined by weighing print.
4. Cut is boned and trimmed by removing flank until a 15 cm diameter roll can be prepared and tied in elastic net.
5. Ends trimmed and 2.5 cm slices taken from both ends for chemical analysis.
6. A 5 cm slice taken from posterior end for raw colour measurement and panel assessment on lean and fat (Scales Raw 1). A macerate is taken for pH, pigment analysis and soluble fat pigments.
7. The remainder is presented to a panel for raw assessment.
8. The 21 cm roll is roasted in oven at 175°C to internal temperature of 74°C. All temperatures recorded by thermocouple.
9. The hot roasted joint is cut 7 cm from the anterior end and judged by a panel for appearance.
10. A 6 cm slice is taken for instrumental colour and texture measurements after cooling.
11. The l.d. muscle from the remainder is cut into 1 cm slices and presented to the panel hot for assessment of odour, colour, texture, flavour and overall acceptability.
12. The data recorded on punch cards, contain 11 variables details of animal; 6 variables chemical analysis; 4 variables texture; 15 variables colour, raw and cooked, lean and fat; 3 variables pH, pigment; 12 variables taste panel, raw and cooked.

measurements are made after cooking. Raw meat is bloomed at +3°C for one hour. The panel assessment of the raw meat is intended to reflect the situation in the retail shop where the whole piece is presented by the butcher and, after cooking the whole joint is again assessed as in the domestic situation before carving. Eating quality is assessed by a panel of at least 10 people on the five scales shown. All members of the Institute staff are required to serve on panels; they are screened for colour blindness, for sensitivity to the standard tastes and for ability to discriminate and judge consistently on a standard series of samples. About one third of the 180 people tested are acceptable for service on taste panels. Texture is measured using blunt jaws on a 1 x 1 cm cross-section of cooked cooled muscle. 10 replicates are taken from each sample and the coefficient of variation within the *longissimus dorsi* is about 25%. The maximum shear force and the total work done are normally used.

Scaling of eating qualities

A cursory examination of the scales used in the MRI method (Table 3) shows that many of the judgments asked for are subjective, that is they depend upon the individual's preferences. The hedonic scales used in the

Table 3. Scales used in sensory assessment of beef in MRI standard method. Abbreviation E-extremely, V-very, M-moderately, S-slightly. The numbers are marks awarded subsequent to the judgements.

Raw 1 Judgements on the whole joint				
Colour of lean	Colour of fat	Ratio of fat/lean	Overall attractiveness	
E dark 4	Entirely satisfactory 0	Much too fatty 3	E attractive	7
V " 3	Dislike S 1	M " " 2	V " "	5
M " 2	" M 2	S " " 1	M " "	3
S " 1	" V much 3	Ideal 0	S " "	1
Ideal 0	" E 4	S under fatty 1	S unattractive	-1
S pale -1		M " " 2	M " "	-3
M " -2	If marked 'dislike'	M much" " 3	V " "	-5
V " -3	state why		E " "	-7
E " -4				

Cooked 1 Judgements on the whole cooked joint, partly slices				
Colour of lean	Colour of fat			
Like E 7	Acceptable 1	Like E 7		
" V much 5	Unacceptable 0	" V much 5		
" M 3		" M 3		
" S 1		" S 1		
Dislike S -1		Dislike S -1		
" M -3		" M -3		
" V much -5		" V much -5		
" E -7		" E -7		

Cooked 2 Judgements on individual hot samples				
Colour of lean	Flavour	Texture	Juiciness	Overall acceptability
E dark 4	Like E 7	E tender 7	E juicy 4	E acceptable 7
V " 3	" V much 5	V " 5	V " 3	V " 5
M " 2	" M 3	M " 3	M " 2	M " 3
S " 1	" S 1	S " 1	S " 1	Just " 1
Ideal 0	Dislike S -1	S tough -1	Dry 0	Just unacceptable -1
S pale -1	" M -3	M " -3		M " -3
M " -2	" V much -5	V " -5		V " -5
V " -3	" E -7	E " -7		E " -7
E " -4				

assessment of the cooked joint and the flavour scores used in the Cooked 2 series are clearly so; in the former case the object is to relate the appearance to the individuals experience, in the last case it is a policy of desperation since there are no recognised absolute standards of meat flavour and no samples of a standard or even reproducible flavour characteristics can be provided to anchor a scale, these subjective descriptions are the only ones available (in other experiments scales of intensity of flavour have been used and in others intensity of off-flavour is appropriate). It is possible in some scales to anchor the centre point of the scale to the ideal, thus the judge is required to compare the sample with his ideal of, for example, lean colour and to select a degree of darkness or paleness; the same scale without the ideal centre point would also be a valid scale but is less stable within a judge. No scale is used with the classical "neither like nor dislike" since such a nebulous description of an attitude is regarded as meaningless: in order to maintain symmetry in the marks on either side of zero a double unit is then necessary. With a describable centre point units can be used.

Experimental design using panels

When measurements are made using instruments there is, in general, small variability due to changes in the machine over time, or it can be eliminated by standardisation. Moreover the same machine is available for use on all samples. Human judgments on the other hand are notoriously unreliable, the variability within a judge within a session being so high that a panel of six or more is necessary to allow even side by side comparisons to be accurate. This variability will be reduced by experience and by instruction aimed at improving awareness and motivation, but care is needed to avoid 'training' which may confuse otherwise clearly perceived concepts.

Hedonic judgments and those anchored to a concept of an ideal will inevitably introduce differences between judges and such differences will very often be statistically significant. It is essential therefore that all samples in an experimental comparison be judged by the same panel in order that the variability between judges can be removed from the analysis and that interactions between judges and treatments can be tested for. For example, if some judges like to eat fat and some find it unappetising, a series of samples of different fat levels will be marked into opposing orders of overall acceptability; the means may be the same but the samples are very different. Such an effect cannot be disclosed without a full analysis of variance which demands orthogonal sets of data.

The major difficulty in setting up experiments on meat quality lies therefore in managing the attendance of panel members. When comparisons can be completed in single sessions and replications achieved within a few days, planned attendance is possible, but when animals are being grown sessions may be held over periods of months and in extended comparisons between breeds and the like, sessions may be required over years. Such comparisons are rarely possible, since illness, holidays, marriage, promotion, transfer and accident over such periods reduce the extent of orthogonal data dramatically. For example the absences recorded in Table 4 amount to only 9% of the possible judge times session total yet the largest orthogonal set taken from the register rejects 51% of the work done (7 panelists x 7 sessions); alternatively 52% is rejected in 2 sets

Table 4. Register of attendances and rearrangement to demonstrate orthogonal data sets.
0 = absence

	Panelists									
	A	B	C	D	E	F	G	H	I	J
Sessions	1							0		
2									0	
3		0								
4										
5										0
6										0
7				0	0					
8										
9										
10	0					0				

	Panelists									
	C	G	D	E	A	F	I	H	B	J
Sessions	4									
8										
9										
5										0
6										0
3									0	
1								0		
2								0		
10					0	0				
7			0	0						

Sets	Panelists	x	Sessions	Data recovered (%)
1	10	x	3	= 30
1	9	x	5	= 45
1	8	x	6	= 48
1	7	x	7	= 49
1	6	x	8	= 48
1	4	x	9	= 36
1	2	x	10	= 20

A computer programme, in Fortran, for the extraction of orthogonal data sets has been written by Mr. J.M.Robinson and can be obtained from MRI.

components of eating quality and sensory methods must be used for flavour and odour. As I have shown, all flavour scales must be hedonic and results will thus reflect the preference of the local panelists. As shown in Table 1 many of the factors which affect preferences arise from the influences of the local culture, hence panel results in different countries cannot possibly be comparable.

For example "bacon" in the USA is a term most usually applied to the cured belly of the pig; it contains a high proportion of fat and is generally cooked by frying until most of the fat has been rendered out and it is served with the collagenous tissue and the lean practically dry and crisp. In the United Kingdom "bacon" is most usually understood to mean the cured loin of the pig, the rashers consisting mostly of lean tissue with a narrow surround of fat; it is generally cooked by drying until the lean is soft and juicy and the fat intact and translucent. The same word is used in the two countries to describe quite different foodstuffs and the two populations are highly critical when presented with the foreign article. In the UK typical USA belly bacon is sold at the lowest price as a cheap food; and in the USA prime UK back bacon is hardly known. Any attempt to use sensory methods to assess the eating quality of bacon in these two countries is obviously doomed. In the MRI work on bacon we devised a standard cooking method in which rashers were suspended and heated dry in a casserole so that rendered fat spread over the lean. Such a method gave a realistic reproduction of the mild conditions typical of the UK breakfast frying without the uneven effect of contact with a heated surface. This method is heavily criticised by US scientists because it does not in any way equate with the US practice; the nevertheless it is valid for UK purposes. The differences in cooking method for bacon may be important; the formation of nitrosamines during frying is predominantly in the fat phase and these substances are also lost by volatilisation, thus longer and hotter treatment might increase formation or decrease the residual levels in the food actually eaten. Such phenomena underline the need for independent studies using local products and techniques, and also emphasises the need for continuous exchanges of information and for collaborative studies at the scientific level before legislative processes advance to far.

Similarly the amount of fat taken home by the French housewife when she purchases beef is very small; the traditional animal in France is large and lean and the French butchery methods are based upon seaming out of the muscle and selling this meat in slices while the fat leaves the retail shop in other forms. In the USA and the UK fat is sold with the lean across the retail counter and the two components are cooked and served together. Fatness is regarded as desirable in the USA appreciation of beef and forms the major criterion in the United States Department of Agriculture grading system which claims to "...help a consumer identify various levels of quality...". Hence a taste panel of Americans will equate fat in a sample to increasing eating quality whereas a French panel will take quite the reverse view. Many other examples could be brought forward especially concerning lamb and mutton, and there are examples too of commercial experiences where meat judged to be of the highest quality in one country finds no market when exported; on the other hand the sheep's eyes and other parts of the carcass not used in western countries are regarded as delicacies elsewhere.

(6 x 8 and 8 x 6); 55% in one set (9 x 5) and as much as 80% in the set taking the only two panelists who attended all 10 sessions. Such a record was achieved in a series of sessions held twice weekly in 5 weeks; much less successful results have been recorded in longer running experiments. One way out of this dilemma is to freeze all samples and complete the tasting sessions in a short time; this is possible with meat since the effect of freezing and thawing is small, but the variation in length of storage time (even at very low temperature) can be significant.

Inter-panel comparisons

When the extraction of orthogonal sets of data results in the destruction of an experiment, as it may do, then comparisons between treatments can be made only by comparing panel means and the residual variance will include the between panelists and panelist x treatment interaction, thus reducing the sensitivity of the comparisons. Should significant differences be obtained between treatments the conclusions are sound but the absence of significance cannot be regarded as conclusive evidence for no difference. It is essential, therefore, to look closely at the design and the analysis of experiments using sensory assessment in the literature before accepting the sometimes over simplified interpretations reported.

Particularly important at the present time are the implications of these conclusions in the context of the international collaborative exercises which are ostensibly designed to harmonise or standardise methodology in different countries. No exception can be taken to comparing the various methods of instrumental analysis (although more attention should be paid to sampling - a major difficulty in an isotropic substance like muscle) but instrumental methods can be used to measure only colour and texture among the

Consumer appreciation and marketing beliefs

If eating quality can be measured, then the effects of the production factors listed in Table 1 can be evaluated objectively and the real importance to the industry and the consumer of each factor assessed. We have examined over 600 beef carcasses at the MRI by the standard method and can analyse the results to display many such effects.

Colour. The colour of the lean of raw meat is perhaps the most important factor in selling meat in the shop. The bright, light red of oxymyoglobin is psychologically attractive and the industry has capitalised on this, the only property of meat which the purchaser can appreciate in the shop, to promote its product. Darker colours result from high pH and from the higher pigment content of older animals; brown colours result from prolonged storage and from extended times on display. In fact none of these circumstances greatly affects the eating quality of the meat and longer stored meat is more tender because it is more adequately aged. On rational scientific grounds colour should play no part in the retailing of meat since pH and age could be determined without reference to colour. Two important consequences of this artificial prejudice against colour other than bright red are that anaerobic packing cannot be used in retail packs because the meat is dark, and secondly it has proved very difficult to introduce frozen retail packs to the housewife because of various differences in appearance.

Fatness. Some people like to eat fat and some people do not; in a recent survey we have shown that close to one half of UK consumers actually reject fat on the plate (Table 5): as I noted above the French consumer rarely sees fat on her plate (at least from beef) whereas the USA consumer sees a great deal. The people who reject visible fat, which is expensive to produce, would of course prefer to buy lean meat and save waste but there is a belief which is commonly expressed in cookery books and by the industry that the lean from a fat animal is superior in eating quality to that from a lean animal. This clearly implies in the UK a distinction between 'beef' breeds and 'dairy' breeds. Table 6 shows that the panel means and standard errors of the means for the various quality components among animals from various breeds examined at MRI give no clear-cut indication of a division in quality according to the beef and dairy breeds or their respective crosses. These experiments have spread over nine years and no orthogonal analysis is possible thus the comparisons are less sensitive than could be. These results support much work in the USA which signally failed to substantiate the belief that fatness contributes to increased tenderness, flavour or juiciness of beef, or that significant differences in eating quality exist between beef from the high USDA grades. In general it appears that the current trend towards more efficient meat production by producing leaner carcasses is not threatening the acceptability of the product except of course to those consumers whose preference is for fat: a careful watch on the balance of production with demand must be kept.

Table 5. Proportions of UK consumers who reject visible fat on the plate. Age groups divided at 16 years.

Age Sex	Total No.	Beef	Pork	Lamb
Boys	122	67	55	62
Girls	116	64	67	68
Men	634	34	38	45
Women	623	42	42	50
Overall	1495	42	43	50

Table 6. Means and standard errors of means of components of eating quality amongst mixed groups of steers and heifers (age 12-24 months). For scales see Table 3.

*Instrument work done (J).

Breed	No	Texture				Flavour		Juiciness		Overall accept.	
		Panel		Instrument*							
		M	SE	M	SE	M	SE	M	SE	M	SE
SxA	11	4.8	.24	95	7	2.8	.17	1.9	.24	2.5	.34
AAxAA	27	3.3	.22	124	6	2.0	.26	1.9	.10	2.1	.15
SSxF	10	3.0	.71	133	13	2.0	.30	1.6	.15	3.2	.33
LxF	12	3.0	.46	155	13	2.1	.30	1.3	.12	2.6	.26
GSxF	11	2.8	.50	135	10	2.0	.24	1.8	.15	3.3	.16
FxF	137	2.4	.14	-	-	1.8	.27	1.2	.06	1.7	.06
HxF	193	2.3	.16	162	6	1.3	.10	1.5	.06	2.3	.07
LRx HF	20	2.2	.39	156	9	1.7	.18	0.9	.12	1.7	.20
SDxF	6	1.8	.49	147	11	2.2	.16	1.2	.23	2.0	.19

A - Ayrshire

AA - Aberdeen Angus

F - Friesian

GS - German Simmental

H - Hereford

L - Limousin

LR - Lincoln Red

S - Simmental

SD - South Devon

SS - Swiss Simmental

Summary

I do not propose to discuss the results presented in this paper in more detail; they have I hope illustrated the points made concerning 1) the limitations on the use of sensory assessments in extended experiments on the eating quality of meat; 2) the inter-relationships between consumer preferences and the definition and measurement of eating quality; 3) the necessity of a cautious approach when the use of sensory assessments are proposed for international standardisation purposes; 4) the necessity of studying the scientific basis of legislation in the local context before generalisations are accepted which may not be valid in particular circumstances.