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EATING QUALITY OF EUROPEAN BEEF ASSESSED AT FIVE RESEARCH INSTITUTES

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SUMMARY

Loin steaks from 10 animals (five of each of two types) from each of eight European countries were assessed for eating quality at five institutes in Denmark, Ireland, England, France and the Federal Republic of Germany. All panels found wide variation in eating quality and many of the steaks were unacceptably tough. Although attempts to relate quality to production factors were often confounded, differences in post-slaughter handling, particularly between producing countries, dominated eating

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quality. Breed, sex, age or fatness had relatively little influence on eating quality in this trial.

A common eight-category scale of tenderness/toughness was used in addition to each institute's usual descriptive scales for tenderness, flavour, juiciness and overall acceptability, employing four to eleven categories. Within panels, attribute scores were not independent and tenderness and flavour in combination were the best predictors of overall acceptability. Between panels, tenderness was highly interrelated, flavour and juiciness poorly interrelated.

These findings, together with estimates of each panel's discrimination and the variation between individual assessors, are discussed in relation to standardisation and equivalence of sensory methodology.

INTRODUCTION

The aim of the meat industry should be to satisfy consumer demands within the confines of efficient economic production. With this objective, research on the quality of beef can be divided into two areas. First, surveys of public opinion, nutritional status, test marketing and acceptability provide information on consumer attitudes and preferences. Secondly, production factors which affect quality can be identified and ranked in order of importance. To estimate the effects of production factors, quality evaluations are carried out in the laboratory using taste panel procedures supported by instrumental and chemical analyses. Unfortunately, these procedures have usually developed independently in different laboratories. Arising from meetings of representatives of meat research institutes within the European Economic Community, standard procedures for sampling and measuring the qualities of raw meat were adopted (Boccard *et al.*, 1981). Instrumental measurement of appearance and composition were standardised and therefore directly compared between institutes. Each institute could relate those measurements to local preferences. Agreement had previously been reached in standardising the classification of beef carcasses (de Boer *et al.*, 1974) and the grading of the freshness of fish (Houwing, 1971). In beef, however, several compositional and structural factors are important in determining texture (Locker *et al.*, 1975) and flavour (Wasserman, 1979) and therefore objective measurements on raw meat cannot reliably predict eating quality. Organoleptic assessments of the quality of cooked meat are therefore essential. Organoleptic assessments of cooked meat, however, cannot be compared between panels since cooking procedures are based on local tradition and preference and, in the absence of international standards for scaling, panels use different descriptions, different numbers of categories and both quantitative and hedonic scales. This paper reports comparisons of eating quality of meat from eight EEC countries assessed at five laboratories.

EXPERIMENTAL

Meat

Representatives from Slagteriernes Forskningsinstitut (SF), Denmark, the Meat Research Institute (MRI), England, The Agricultural Institute (AFT), Ireland, the Institut National de la Recherche Agronomique (INRA), France, and Bundesanstalt für Fleischforschung (BF), Federal Republic of Germany, Rijksstation voor Veevoeding, Melle-Gontrode, Belgium, Istituto di Produzione Animale, Facola di Agraria, Universita Napoli, Portici, Italy, and Centraal Instituut voor Voedingsonderzoek TNO, Zeist, The Netherlands, procured meat samples from ten animals slaughtered in their locality representing two types (five of each type) suited to local consumption. Animals were slaughtered and butchered in EEC licensed slaughterhouses and cutting rooms during July to September, 1979. Descriptions of the meat from these sixteen sources are summarised in Table 1.

Sampling of steaks

On average, meat was cut 8 days after slaughter. Steaks from sources 7, 8, 11 and 12 were cut between 2 and 4 days after slaughter, and those from sources 1, 2, 9 and 10 between 12 and 16 days after slaughter. Slices (approximately 2·5 cm thick) of the *M. longissimus dorsi* (LD) posterior to the 11th rib were cut and numbered 1 to 8 for the left (L) and right (R) sides. Samples L1, R1 and L2 were allocated to AFT; L3, R3 and R2 to SF; L4, R4 and L5 to INRA; L6, R6 and R5 to BF; and L7, R7 and L8 to MRI. The last code in each institute denoted the steak to be used for instrumental determinations. Steaks were packed under vacuum and stored below $-20\,^{\circ}C$ for 2 to 9 months. The frozen steaks were air freighted to England where they were allocated and redistributed to SF, MRI, AFT, INRA and BF for organoleptic assessment.

Organoleptic assessments

Each testing institute (SF, MRI, AFT, INRA, BF) used its standard methodology for eating quality evaluation and all tested the steaks (hot) in the same order.

At AFT, Dublin, steaks were thawed and then grilled on a catering grill set at 'high' for 7 min each side, producing a medium to well done steak with centre temperature about $70\,^{\circ}C$. Steaks were cut and then judged by ten selected assessors from the institute's staff using the scales given in Table 2.

At BF, Kulmbach, steaks were thawed overnight and grilled for 6 min in a contact grill (Turmix, Switzerland). Cooking losses ranged from 10 to 42 % (mean 28 %); sources 13 and 14 lost 16 % of the thawed weight and sources 11 and 12 lost 39 %. Steaks were cut and judged by six assessors selected from the institute's staff, using the scales given in Table 3, where an English translation is also provided.

At INRA, Theix, steaks were thawed and grilled to a centre temperature of $50\,^{\circ}C$. They were cut and judged by twelve selected assessors from the institute's staff using

TABLE 1
DESCRIPTION OF THE ORIGINS OF BEEF STEAKS

Source	*Breed*	*Sex*	*Approximate age (months)*	*Place of slaughter*	*Carcass weight (kg)*	*Approximate fatness (EAAP)*
1	CH, Danish black and white	Heifer	18–36	Esbjerg, Denmark	210–272	3^- to 4
2	Danish black and white, RDM, CH	Cow	48–60		244–282	3^-
3	BF	Steer	16–18	Torrington, England	316–344	3 to 5^-
4	BFx	Steer	18–24		272–369	3 to 4
5	White-blue of Belgium	Bull	15–18	Melle, Gontrode, Belgium	370–411	1^+ to 3^-
6	White-red of Belgium	Bull	15–18		286–389	1^+ to 3^-
7	ITF	Bull	18	Naples, Italy	265–298	2^+ to 3^-
8	Brown Alpine	Bull	18		242–314	2 to 2^+
9	CH	Cow	36–60	Theix, France	306–362	2^- to 3
10	CHx	Bull	18–20		306–356	1 to 2
11	DF	Cow	60–72	Druten, Zeist, The Netherlands	238–278	2^+ to 3^-
12	Dutch red-white	Bull	18		295–323	3^- to 3
13	GS	Bull	16–18	Kulmbach, German FR	290–320	1^+ to 3
14	GS	Cow	36–60		260–300	2^- to 4^-
15	H × BF	Heifer	18–36	Dublin, Ireland	204–219	2 to 4^-
16	H × BF, H × BSH, BSH	Steer	18–36		266–294	2 to 4^-

RDM = Danish red; CH = Charolais; BF = British Friesian; ITF = Italian Friesian; DF = Dutch Friesian; GS = German Simmental; H = Hereford; BSH = British Short-horn.

TABLE 2
TASTE PANEL EVALUATION OF EATING QUALITY OF BEEF—AFT AND MRI

MRI		*AFT*	
Juiciness		Juiciness	
Extremely juicy	(4)	Extremely juicy	(4)
Very juicy	(3)	Very juicy	(3)
Moderately juicy	(2)	Moderately juicy	(2)
Slightly juicy	(1)	Slightly juicy	(1)
Dry	(0)	Dry	(0)
Flavour intensity		Flavour intensity	
Strong beef flavour	(3)	Strong beef flavour	(3)
Moderate beef flavour	(2)	Moderate beef flavour	(2)
Weak beef flavour	(1)	Weak beef flavour	(1)
No beef flavour	(0)	No beef flavour	(0)
		Flavour	
		Like very much	(5)
		Like moderately	(3)
		Like slightly	(1)
		Dislike slightly	(−1)
		Dislike moderately	(−3)
		Dislike very much	(−5)
Texture		Texture	
Extremely tender	(7)	Extremely tender	(7)
Very tender	(5)	Very tender	(5)
Moderately tender	(3)	Moderately tender	(3)
Slightly tender	(1)	Slightly tender	(1)
Slightly tough	(−1)	Slightly tough	(−1)
Moderately tough	(−3)	Moderately tough	(−3)
Very tough	(−5)	Very tough	(−5)
Extremely tough	(−7)	Extremely tough	(−7)
Overall acceptability		Overall acceptability	
Extremely acceptable	(7)	Extremely acceptable	(7)
Very acceptable	(5)	Very acceptable	(5)
Moderately acceptable	(3)	Moderately acceptable	(3)
Just acceptable	(1)	Just acceptable	(1)
Just unacceptable	(−1)	Just unacceptable	(−1)
Moderately unacceptable	(−3)	Moderately unacceptable	(−3)
Very unacceptable	(−5)	Very unacceptable	(−5)
Extremely unacceptable	(−7)	Extremely unacceptable	(−7)

If any sample marked unacceptable, please state why:

the scales given (with English translation) in Table 4. Assessors discussed their assessments periodically with the panel leader.

At MRI, Langford, steaks were thawed overnight, after which drip losses varied from 1% in source 2 to 7% in sources 5 and 8. They were trimmed to 2·5 cm thickness, turned under the grill every 2 min and cooked to a centre temperature of 75 °C. The steaks were cut and judged by fourteen experienced assessors using scales given in Table 2.

TABLE 3
TASTE PANEL EVALUATION OF EATING QUALITY OF BEEF STEAKS—BF

Saftigkeit		Juiciness
Sehr saftig	(6)	Very juicy
Saftig		Juicy
Etwas saftig		Slightly juicy
Etwas trocken		Slightly dry
Trocken		Dry
Sehr trocken	(1)	Very dry
Geschmack (aroma)		Flavour
Ausgezeichnet	(6)	Excellent
Sehr gut		Very good
Gut		Good
Befriedigend		Satisfactory
Ausreichend		Sufficient
Wenig ausreichend	(1)	Insufficient
Zartheit		Tenderness
Sehr zart	(6)	Very tender
Zart		Tender
Etwas zart		Slightly tender
Etwas zäh		Slightly tough
Zäh		Tough
Sehr zäh	(1)	Very tough
Gesamteindruck		Overall
Ausgezeichnet	(6)	Excellent
Sehr gut		Very good
Gut		Good
Befriedigend		Satisfactory
Ausreichend		Sufficient
Mangelhaft	(1)	Insufficient

All scales were subsequently scored 1 to 6 as indicated.

At SF, Roskilde, steaks were thawed at 20 °C for 1–2 h and trimmed to 2·5 cm thickness. Steaks were heated without additional fat on a griddle at 170 °C. Steaks were turned after cooking for 3, 6 and 8 min and cooked for 9·5 to 10·5 min, depending upon thickness—a method designed to produce fried steaks with pink centres. The steaks were assessed by nine housewives from a nearby town who were experienced in taste panel work and whose ages ranged from 33 to 65 (averaging 52), using the scales given (with English translation) in Table 5.

Tasting was arranged in two groups of sessions. In the first, two animals, representing the two types from local production within a country, were compared with two animals representing two types of local production from another country (see Table 1). Thus each session compared four animals. Comparisons of sixty animals from six countries (excluding Belgium and The Netherlands) were completed in fifteen sessions. In the second, four animals (one from each of sources 5, 6, 11 and 12) were compared in each of five sessions. Sources 5, 6, 11 and 12 (see Table 1) were chosen because Belgium and The Netherlands are not major exporters of beef. At each institute the positions of samples within steaks were distributed randomly among assessors and the ten sessions were held over about a 4-week

TABLE 4
TASTE PANEL EVALUATION OF EATING QUALITY OF BEEF STEAKS—INRA

Jutosité succulence		Juiciness
Très juteux	(8)	Very juicy
Juteux		Juicy
Assez juteux		Moderately juicy
Légèrement juteux		Slightly juicy
Légèrement sec		Slightly dry
Assez sec		Moderately dry
Sec		Dry
Très sec	(1)	Very dry
Intensité de la flaveur de boeuf		Intensity of beef flavour
Très forte	(8)	Very strong
Forte		Strong
Assez forte		Moderately strong
Légèrement forte		Slightly strong
Légèrement faible		Slightly weak
Assez faible		Moderately weak
Faible		Weak
Très faible	(1)	Very weak
Tendreté globale		Overall tenderness
Très tendre	(8)	Very tender
Tendre		Tender
Assez tendre		Moderately tender
Légèrement tendre		Slightly tender
Légèrement dur		Slightly tough
Assez dur		Moderately tough
Dur		Tough
Très dur	(1)	Very tough
Préférence		Acceptability
Très bon	(8)	Very good
Bon		Good
Assez		Moderate
Plutôt bon		Rather good
Plutôt mauvais		Rather poor
Assez mauvais		Moderately poor
Mauvais		Poor
Très mauvais	(1)	Very poor
Remarques		
Flaveurs anormales, etc....		

Assessments were subsequently scored 1 to 8 as indicated.

period, beginning in November at MRI and ending in the following March at SF. All panels were conducted using the general recommendations for environment, panel conduct and motivation (Amerine *et al.*, 1965; ASTM, 1968; Prell, 1976; BSI, 1980).

Chemical and instrumental measurements

Intramuscular fat was determined by solvent extraction on steaks L5 at BF and

TABLE 5
TASTE PANEL EVALUATION OF EATING QUALITY OF BEEF—SF

Saftighed		Juiciness
Ideel	(5)	Ideal
Meget fin (saftig)		Excellent
Fin (saftig)		Extremely good
Meget god (saftig)		Very good
God (saftig)		Good
Hverken god eller darlig		Neither good nor bad
Ubetydelig tør		Marginally dry
Lidt tør		Slightly dry
Tydelig tør		Dry
Meget tør		Very dry
Slet	(−5)	Poor
Egensmag		Flavour
Ideel	(5)	Ideal
Meget fin		Excellent
Fin		Extremely good
Meget god		Very good
God		Good
Hverken god eller darlig		Neither good nor bad
Ubetydelig afsmag		Marginal off flavour
Let afsmag		Slight off flavour
Tydelig afsmag		Distinct off flavour
Kraftig afsmag		Strong off flavour
Slet	(−5)	Poor
Mørhed		Tenderness
Ideel	(5)	Ideal
Meget fin (mør)		Excellent
Fin (mør)		Extremely good
Meget god (mør)		Very good
God (mør)		Good
Hverken god eller darlig		Neither good nor bad
Ubetydelig sej, hard		Marginally tough
Lidt sej, hard		Slightly tough
Tydelig sej, hard		Distinctly tough
Meget sej, hard		Very tough
Slet	(−5)	Poor
Farve		Colour
Ideel	(5)	Ideal
Meget fin		Excellent
Fin		Extremely good
Meget god		Very good
God		Good
Hverken god eller darlig		Neither good nor bad
Ubetydeligt misfarvet		Marginally discoloured
Let misfarvet		Slightly discoloured
Tydeligt misfarvet		Distinctly discoloured
Kraftigt misfarvet		Strongly discoloured
Slet	(−5)	Poor

Bemaerkninger:

All scales were subsequently scored −5 through 0 to 5 as indicated.

by NMR on dried powder from R5 at INRA; collagen and nitrogen on steak R5 at INRA and water-holding capacity on L5 at BF using the Grau–Hamm filter paper press method (Hamm, 1976). Toughness of grilled LD was measured on L5 using Warner–Bratzler shear (Hurwicz & Fischer, 1954) and on L8 using Volodkevich-style jaws (Rhodes *et al.*, 1972). Warner–Bratzler 'shear force' values were highly correlated ($r = 0{\cdot}9$) with Volodkevich 'work done' values but analysis of variance revealed that the latter method was the more discriminating (higher variance ratio for 'source') and only that method is reported here. Values from both methods were highly correlated ($r = 0{\cdot}8$) with panel tenderness scores.

Analyses

Within panels, analyses of variance were performed on each attribute. Attributes were combined by stepwise multiple regression in predicting overall acceptability. Panels were compared by ranking of the sixteen sources of beef and by correlation using all animals.

RESULTS

In view of the widely differing beef production systems used (Table 1), the results of quality assessments are presented as means for each of the sixteen sources of production for each attribute to quantify the influence of production and to compare assessments between panels.

Chemical, instrumental and colour determinations (Table 6)

Steaks from seven of the eighty animals were dark with pH values ranging from 6·0 to 6·8. Five of the seven dark cutters were bull beef from source 13. Overall intramuscular fat content averaged 2·7 %, the leaner samples (< 1·7 %) were bull beef from Belgium (sources 5 and 6) and from source 10 (Table 1) and the fatter beef (> 3·7 %) was derived from heifer and steers. Loosely bound water varied significantly between sources and steaks with the highest value (30 %, source 8) had the highest losses on thawing (6·8 %) while those with the lower values (18 %, sources 2, 4 and 8) had the lowest losses on thawing (1 to 2 %). Connective tissue content varied from 2·4 to 4·3 μmoles hydroxyproline per gramme between sources, bull beef having values of 3 μg/g or greater. Pigment concentrations in LD averaged 3·8 mg/g and high values (up to 5 mg/g) were usually associated with older cow beef; the exception was beef from 3- to 5-year-old Charolais cows which had average pigment concentrations. Colour of the grilled steaks (assessed subjectively at SF) was judged to be good and there was little variation between sources (1·5 categories of an eleven-category scale, Table 5). Toughness values varied from 128 to 425 mJ between sources and most of that variation occurred between country of origin. Toughness was not associated with pre-slaughter production variables (Table 1).

TABLE 6

CHEMICAL COMPOSITION OF RAW MUSCLE AND COLOUR AND TOUGHNESS OF COOKED *M. longissimus dorsi* FROM THE SIXTEEN SOURCES

Values are source means together with approximate least significant difference (LSD)

Source	*Pigment* (*mg/g*)	pH_{ult}	*Fat* (%)	*FFDM* (%)	*Water* (%)	*Loosely bound water* (%)	*Hydroxy-proline* (*μmoles/g*)	*Nitrogen* (*Moles N_2/100 g*)	*Cooked colour* (*−5 to +5*)	*Instron work-done* (*mJ*)
1	3·9	5·6	4·1	22·8	72·1	22·4	2·4	0·12	2·6	128
2	4·9	5·7	3·5	23·0	72·6	19·9	2·7	0·12	2·3	133
3	4·5	5·6	4·2	22·4	72·7	21·4	2·8	0·12	1·8	236
4	4·1	5·7	2·9	22·3	73·7	19·8	2·6	0·13	2·4	234
5	3·6	5·6	1·1	23·2	74·8	26·6	3·0	0·13	2·2	241
6	2·8	5·6	1·6	22·4	75·3	28·8	3·1	0·13	1·5	234
7	3·2	5·7	2·6	22·3	74·5	23·2	3·3	0·13	1·9	271
8	2·9	5·7	1·8	23·1	74·2	30·2	3·9	0·13	2·2	317
9	3·4	5·6	3·5	22·4	72·8	19·1	2·9	0·13	2·0	198
10	3·4	5·7	1·2	22·7	75·0	25·3	3·8	0·14	2·2	281
11	5·0	5·6	2·9	22·8	73·7	23·6	2·8	0·13	1·0	425
12	3·6	5·7	2·9	22·8	73·2	26·8	4·3	0·13	1·9	334
13	3·3	6·1	2·7	22·0	74·2	24·6	3·3	0·13	1·2	203
14	4·4	5·6	2·9	22·3	74·0	24·0	2·6	0·13	2·3	270
15	4·1	5·6	2·3	22·0	74·6	25·4	2·6	0·13	1·9	207
16	3·8	5·7	2·2	22·1	74·5	26·0	2·8	0·13	2·5	226
LSD (5%)	0·8	0·4	1·8	0·9	1·8	4·6	0·5	0·00	0·5	26

FFDM: fat free dry matter.

Organoleptic assessments

On average, beef from all sources was judged to be slightly juicy (Table 7). Values at SF were only slightly higher than at AFT and MRI with INRA and BF intermediate. Variation in juiciness between sources was generally low: 16 % of the scale used by the MRI panel and 25 % of the scale used by the INRA panel. Source was judged by the BF panel to have the greatest influence (40 % of the scale) on juiciness. The ranking of sources for juiciness was inconsistent and the variation in juiciness, judged by each panel or by using the average of the five panels, was unrelated to that of pH, fat, moisture or loosely bound water contents (Table 6).

TABLE 7

VARIATION IN JUICINESS OF BEEF STEAKS ASSESSED IN FIVE INSTITUTES

Juiciness was assessed at SF on a scale of −5 to 5; at INRA on a scale of 1 to 8, at BF on a scale of 1 to 6 and at AFT and MRI on a scale of 0 to 4.

Values are means and approximate least significant difference (LSD) for the sixteen sources of beef arranged in order of juiciness average

	Testing institute				
Source	*SF*	*INRA*	*BF*	*AFT*	*MRI*
16	3·5	5·1	5·1	2·0	1·6
1	3·5	5·8	3·9	1·6	1·8
14	3·1	4·2	5·1	1·8	1·6
6	2·9	4·7	4·4	1·8	1·7
13	2·4	4·7	5·0	1·8	1·4
5	3·2	4·7	3·9	1·8	1·6
15	2·3	4·6	4·8	1·8	1·3
4	2·8	5·4	3·2	1·5	1·6
2	2·4	5·6	3·6	1·2	1·7
7	2·6	5·2	3·6	1·5	1·5
8	2·7	4·9	3·6	1·3	1·7
10	2·3	5·1	4·2	1·1	1·2
9	2·2	4·8	4·0	1·1	1·6
3	2·0	5·0	3·5	1·1	1·6
12	1·7	4·7	2·7	1·1	1·8
11	1·2	3·8	2·6	0·8	2·0
Means	2·6	4·9	4·0	1·5	1·6
LSD (5 %)	0·5	0·5	0·4	0·4	0·3

Overall, the flavour of the steaks was assessed slightly above the scale mid-point at each institute (Table 8), i.e. equivalent to good/slightly strong flavour. Each testing institute agreed that there was little variation between sources which ranged from 10 % (AFT) to 25 % (SF and INRA) of the regional scales. The ranking of meat sources by flavour was inconsistent between institutes. Flavour was not associated consistently with sex or fattiness, although high pH beef (source 13) lacked flavour and was judged worst or equal worst by all except the BF panel.

Source of production markedly influenced texture (Table 9). On the common scale (−7 to 7) sources ranged from 4·6 (very tender) to −4·6 (very tough), i.e. 9·2

TABLE 8

VARIATION IN INTENSITY OF BEEF FLAVOUR ASSESSED IN FIVE INSTITUTES

Beef flavour was assessed at SF on a scale of −5 to 5; at INRA on a scale of 1 to 8; at BF on a scale of 1 to 6; at AFT (1) and MRI on a scale of 0 to 3 and at AFT (2) on a scale of −5 to +5.

Values are means and approximate least significant difference (LSD) for sixteen sources of beef arranged in order of flavour average

Source	*Testing institute*					
	SF	*INRA*	*BF*	*AFT* (1)	*AFT* (2)	*MRI*
1	2·7	5·2	4·4	2·1	3·1	1·9
2	2·1	5·6	4·5	2·1	2·6	2·0
14	2·4	5·1	3·7	2·1	1·5	1·9
4	1·2	5·1	4·0	2·1	2·3	1·8
3	1·4	5·0	3·9	1·9	1·9	1·9
10	1·7	5·4	3·4	1·8	1·2	1·7
9	1·5	5·0	4·0	1·8	1·3	1·6
6	1·7	4·5	3·9	1·9	1·9	1·7
7	1·9	4·8	3·5	1·7	2·0	1·7
5	1·5	4·9	3·6	1·7	2·0	1·8
16	0·8	4·8	3·6	2·0	1·8	1·9
8	1·6	4·3	3·4	1·7	1·7	1·7
12	1·2	4·5	3·4	1·8	0·8	1·8
15	0·0	5·0	3·8	1·9	2·5	1·9
11	0·6	5·1	3·2	1·7	−0·5	1·8
13	0·3	3·6	3·8	1·7	1·6	1·3
Means	1·4	4·9	3·8	1·9	1·7	1·8
LSD (5%)	0·6	0·5	0·4	0·3	0·9	0·3

units (66%) of the fourteen-point scale. There was good agreement in ranking of sources between institutes, whether using their own scales or the common scale provided (MRI and AFT scale). There was no significant interaction between panel and source when the common scale was used (Table 9). Sources 8, 11, 12 and 14 were judged to be tough by all testing institutes using the common scale, and sources 1 and 2 were judged by all testing institutes to be more tender than average. Tenderness was not influenced consistently by the pre-slaughter production factors and major variations must have been induced post-slaughter. From experience it is probable that cold shortening toughness had been induced in the very tough meat (sources 8, 11 and 12). Wide variations in rate of cooling were recorded; the temperature in the deep rounds ranged from 8 to 20 °C 24 h after slaughter. Those cooled to 8 °C (sources 13 and 14) produced the toughest meat; those cooled to 10 °C or above (sources 1, 2, 4 and 15) were among the most tender. Differences in ageing time were also important since meat (sources 3, 7, 8, 11 and 12) aged for 2 to 4 days was tougher than meat (sources 1, 2, 9 and 10) aged for 12 to 16 days.

Acceptability (Table 10) of the meat as grilled loin steaks varied widely from just/moderately unacceptable (unsatisfactory/poor) in sources 8, 11, 12 and 13 to moderately acceptable (good) in sources 1 and 2. Ranking of sources for acceptability was similar to that for tenderness (Table 9).

TABLE 9

VARIATION IN BEEF TENDERNESS ASSESSED IN FIVE INSTITUTES

Tenderness was assessed at SF on a scale of −5 to 5; at INRA on a scale of 1 to 8; at BF on a scale of 1 to 6 and at AFT and MRI on a common scale of −7 to +7.

(a) Means and approximate least significant difference (LSD) for the sixteen sources of beef arranged in order of tenderness average

	Testing institute Regional scales			*Testing institute Common scale*				
Source	*SF*	*INRA*	*BF*	*AFT*	*MRI*	*BF*	*INRA*	*SF*
1	4·1	7·3	4·9	4·5	4·0	3·5	5·5	5·6
2	2·6	6·7	4·4	2·2	3·4	3·0	4·4	3·5
4	2·0	6·2	4·1	2·0	1·8	1·5	3·4	2·6
15	1·0	5·4	3·9	1·7	0·8	1·5	1·8	1·4
7	1·4	5·6	3·7	1·8	0·3	0·6	2·1	1·7
16	0·7	5·2	4·1	0·9	0·0	2·1	1·3	1·0
3	0·6	5·0	3·9	0·2	1·0	1·3	1·0	0·6
6	0·6	5·1	3·7	0·7	0·7	0·0	1·2	0·4
10	0·2	5·3	3·5	0·1	0·5	−0·2	1·5	0·0
9	0·0	5·2	3·4	0·0	0·0	−0·3	1·4	0·1
13	−0·6	4·6	4·1	1·0	−0·8	1·7	0·1	−0·8
5	−0·2	4·6	3·5	0·7	−0·1	−0·3	0·1	−0·3
14	−2·5	3·1	3·4	−0·9	−1·6	−0·2	−2·9	−3·6
8	−1·5	3·4	2·6	−0·8	−2·5	−2·3	−2·1	−2·2
12	−2·8	2·8	2·4	−2·5	−2·8	−2·9	−3·5	−3·9
11	−3·9	2·3	1·9	−4·7	−3·4	−4·0	−4·5	−5·2
Means	0·1	4·9	3·6	0·4	0·1	0·3	0·7	0·1
LSD (5%)	0·7	0·5	0·4	1·1	0·9	1·1	1·0	1·1

(b) *Analysis of variance*

Data (common scale) were average panel scores of sixty samples of beef (excluding sources 5, 6, 11 and 12) assessed at SF, INRA, BF and MRI.

	df	*ms*	F *ratio*
Source (S)	11	79·3	17·4*
Panel (p)	3	8·1	1·8
S × p	33	3·2	0·7
Residual	192	4·6	
Total	249	7·5	

*$P < 0.001$.

Comparison of organoleptic assessments between panels

Because of substantial differences in methodology between panels, the discrimination and the relationships of attributes were calculated within each panel in addition to the relationships between panels. Within panels, analysis of variance was performed for 'source' and 'assessor' using all sources except 5, 6, 11 and 12 (Table 11), i.e. from the first group of tastings (see organoleptic assessment section). Used in this context, the larger the variance (F) ratio for source, the better was the panel able to discriminate between sources. Analysis of variance was also performed using sources 5, 6, 11 and 12 (i.e. the second group of tastings) to determine the interaction between source and assessor.

TABLE 10

VARIATION IN OVERALL EATING QUALITY ASSESSED IN INSTITUTES

Preference (scale of 1 to 8) was assessed at INRA, overall impression (scale of 1 to 6), at BF, and overall acceptability (scale of −7 to +7) at AFT and MRI.

Values are means and approximate least significant difference (LSD) for sixteen sources of beef arranged in overall rank order

	Testing institute			
Source	*INRA*	*BF*	*AFT*	*MRI*
1	6·6	4·4	3·8	3·4
2	6·4	4·2	3·4	3·1
4	5·8	3·8	2·9	2·0
15	5·1	4·0	3·0	1·5
3	5·1	3·7	2·2	2·3
16	5·3	4·0	2·6	1·1
7	5·2	3·5	2·7	1·4
6	4·9	3·9	2·3	1·5
5	4·8	3·6	2·2	1·4
10	5·3	3·5	1·6	1·5
9	5·3	3·7	1·5	1·1
14	4·1	3·8	1·6	0·2
8	4·0	3·1	1·4	−0·6
13	3·4	4·0	1·8	−1·6
12	3·2	2·8	0·3	−1·4
11	2·8	2·3	−1·3	−1·7
Means	4·8	3·6	2·0	1·0
LSD (5%)	0·5	0·4	0·9	0·9

TABLE 11

COMPARISON OF SENSORY EVALUATION BETWEEN FIVE INSTITUTES

Values are variance ratios from analysis of variance using all sources except 5, 6, 11 and 12

		Testing institute			
	SF	*INRA*	*BF*	*AFT*	*MRI*
Juiciness					
Source	7·0	5·6	22·9	(6·7)†	2·3
Assessor	29·2	2·8	10·6	(13·7)	20·9
Flavour					
Source	10·6	8·6	4·9	(2·7)‡	5·1
Assessor	5·5	7·0	11·7	(6·9)	19·6
Tenderness					
Source	32·1	38·8	11·5	(13·3)†	28·5
Assessor	5·8	2·2	2·5	(15·0)	15·4
Tenderness (common)					
Source	31·4	38·8	11·2	(13·3)†	28·5
Assessor	4·9	2·2	1·3	(15·0)	15·4
Acceptability					
Source	—	31·5	7·5	(31·3)†	20·7
Assessor	—	5·8	6·4	(15·0)	20·9

† All sources except 3, 4, 13 and 14.

‡ Values using scale of −5 to +5 were 10·3 for source and 14·0 for assessor.

In assessing juiciness, there was least variation between assessors at INRA. The panel at BF had by far the highest variance ratio for source (Table 11) and the greatest range of assessments (Table 7), showing that it was by far the most discriminating panel, but it was also the only panel in which the source × assessor interaction was significant.

Evaluation of flavour at each institute (Table 11) showed that the variance ratios for assessors at MRI and BF were twice those at the other institutes. Sources were discriminated best at SF and worst at AFT and MRI, with BF and INRA intermediate and differing little from each other. There was no significant interaction between source and assessor at any institute.

For tenderness assessments (Table 11) variation between assessors was much higher at AFT and MRI than at BF, INRA and SF. As a panel, BF were least discriminating and there was little difference in the ability of SF, INRA and MRI panels to discriminate. Only at SF was there a significant ($P < 0{\cdot}05$) interaction between source and assessor using the common and local scales. At BF and SF, panel average assessments using the regional scales (BF, six-category; SF, eleven-category) were highly correlated ($r > 0{\cdot}97$) with those when using the common (eight-category) scale. Use of the common scale did not affect the ability of the panel to discriminate between sources and did not affect variation between assessors at SF and reduced variation between assessors at BF.

Variation in acceptability between assessors (Table 11) at AFT and MRI was similar and about 3–4 times that between assessors from INRA and BF. Acceptability between sources was discriminated poorly at BF. There was little difference in discrimination between panels at INRA, AFT and MRI. Interaction between source and assessor was not significant in any panel.

The interrelationships between attributes within panels are given in Table 12.

TABLE 12

RELATIONSHIP BETWEEN QUALITY ATTRIBUTES AT FIVE TESTING INSTITUTES

Average taste panel scores were calculated for each attribute for each animal. Values are the percentages of variation (correlations) and the percentage of overall acceptability (regression) accounted for by variations in other attributes. All correlation coefficients were positive

(a) *Simple correlations*

	MRI			*BF*			*INRA*			*AFT*			*SF*		
	T	*F*	*J*	*T*	*F*	*J*	*T*	*F*	*J*	*T*	*F*	*J*	*F*	*J*	*Colour*
Tenderness (T)													2	10	9
Flavour (F)	0			44			2			4				28	34
Juiciness (J)	0	3		20	5		45	4		18	0				43
Acceptability	74	12	0	82	63	39	70	28	41	79	13	18	—	—	—

(b) *Multiple stepwise regressions*

	MRI	*BF*	*INRA*	*AFT*
Tenderness	74	82	70	79
Tenderness and flavour	82	88	87	82
Tenderness, flavour and juiciness	82	96	87	82

Scores for tenderness, flavour and juiciness were independent only at MRI. Juiciness was strongly associated with tenderness at INRA and with flavour at BF. At AFT panel average scores for flavour intensity were significantly correlated ($r = 0{\cdot}4$) with hedonic flavour scores. Tenderness was the best single predictor of acceptability and accounted for 70 to 82% of the variation in acceptability. Other single attributes were poor predictors, excepting flavour at BF which accounted for 63% of the variation in acceptability. In combination with tenderness, flavour contributed a further 17% to acceptability at INRA but only 3% at AFT. Only at BF did juiciness contribute further when tenderness, flavour and juiciness accounted for 96% of the variation in acceptability.

The interrelationships of attributes between institutes are given in Table 13. Assessment of juiciness at MRI was not significantly related to that at any other panel and juiciness at INRA was not related to that at BF. Other relationships were significant but correlation coefficients were too low for juiciness to be predicted across panels. On average, variation in juiciness judged by one panel accounted for

TABLE 13

RELATIONSHIP OF QUALITY ASSESSMENTS BETWEEN THE FIVE TESTING INSTITUTES

Average taste panel scores were calculated for each attribute for each of the eighty animals. Values are correlation coefficients between institutes. Values for tenderness using the common scale, values in parentheses using regional scale. With $r = 0{\cdot}22$, $P = 0{\cdot}05$; with $r = 0{\cdot}28$, $P = 0{\cdot}01$ and with $r = 0{\cdot}36$, $P = 0{\cdot}001$.

	AFT	*INRA*	*BF*	*MRI*
Juiciness				
SF	0·28	0·29	0·29	0·01
AFT	1·00	0·21	0·37	−0·10
INRA		1·00	0·08	−0·04
BF			1·00	−0·18
MRI				1·00
Flavour				
SF	0·33	0·37	0·26	0·30
AFT (0 to 3)	1·00	0·41	0·31	0·50
INRA		1·00	0·26	0·51
BF			1·00	0·22
MRI				1·00
Tenderness				
SF	0·82 (0·82)	0·94 (0·94)	0·81 (0·83)	0·88 (0·88)
AFT	1·00	0·80	0·69 (0·73)	0·74
INRA		1·00	0·79 (0·83)	0·89
BF			1·00	0·83 (0·85)
MRI				1·00
Acceptability (preference)				
SF	—	—	—	—
AFT	1·00	0·74	0·65	0·65
INRA		1·00	0·64	0·84
BF			1·00	0·65
MRI				1·00

only 8 % of that judged by any other panel. Assessments of the intensity of flavour were significantly related across panels but, at best (INRA with MRI), flavour intensity measured at one panel accounted for only 26 % of the variation of that in another panel.

Correlation coefficients between panels using intensity categories for flavour (AFT, INRA, MRI) were generally higher (0·4, 0·5, 0·5) than those in which panels used hedonic descriptions (SF, BF) (0·2 to 0·4).

Assessments of tenderness were highly correlated across institutes. Tenderness measured at one institute accounted for between 48 and 88 % of that assessed in another institute. Plots of tenderness scores showed that those relationships were essentially linear and the slopes did not differ significantly.

Acceptability scores correlated significantly between panels and the values of the correlation coefficients (0·65 to 0·82) were between those for flavour and tenderness (Table 13). Since acceptability was judged using different scales, further comparisons were made from rankings (Table 14). Although there was general agreement in ranking, the largest variation from the average rank was found at BF and this was due mainly to a strong preference (together with AFT) for source 13. BF also showed a particular preference for source 14 and UK for source 3. These biases in

TABLE 14

ACCEPTABILITY OF MEAT FROM SIXTEEN SOURCES ASSESSED AT FOUR INSTITUTES

For each institute, animals were ranked in acceptability; the least acceptable scored 1 and the most acceptable, 80. Values given are rank totals of the five animals representing each source; thus, if animals from one source had been ranked as the five least acceptable, the rank total would have been 15; similarly, if they had been ranked the five most acceptable, the total would have been 390. Sources are arranged in overall rank order

	Institute			
Source	*INRA*	*BF*	*AFT*	*MRI*
1	370	372	353	374
2	366	327	333	347
4	309	249	289	265
15	224	284	299	225
16	250	287	252	199
3	223	219	207	298
6	217	251	226	231
7	237	165	255	211
10	246	185	177	227
9	242	214	151	195
5	187	185	210	216
14	116	250	166	174
13	68	265	184	65
8	120	112	160	115
12	85	100	103	75
11	40	30	18	57

acceptability were not confined to beef of one sex, age or carcass fatness categories (Table 1) nor to differences in intramuscular fat, collagen or colour of lean (Table 6). Sources 13 and 14 were judged slightly more tender (Table 9) and more juicy (Table 7) by the BF and AFT panels; source 13 was ranked higher and 14 lower in flavour by the BF panel. The MRI panel scored and ranked source 3 for tenderness, juciness and flavour similarly to the other panels. Similar conclusions were reached by analysing the ranking of acceptability of individual animals but the data are not included.

DISCUSSION

Each of the five institutes has a part of its meat programme devoted to studying the influence of production on quality. With that long-term aim, the approaches of each institute have been broadly similar. First, standardised sensory evaluation was essential and each institute used an experienced panel of between six and fourteen assessors drawn from institute staff except at the Danish Institute where housewives were employed. Those housewives were generally older than assessors at other institutes but assessors are usually selected on ability, not age (Amerine *et al.*, 1965). Secondly, all institutes used verbal category scales from the fifteen or so established types of test (Prell, 1976). Assessments of tenderness and juiciness had the greatest uniformity between institutes; both were analytical scales. Bipolar scales were used most frequently: at INRA and BF, 'tender', 'tough', 'juicy' and 'dry' were used as penultimate categories with the intermediate and extremes qualified with adjectives. At MRI and AFT adjectival categories were used throughout except for 'dry', producing a shorter unipolar scale for juiciness. Flavour scales differed most; quantitative scales were used by AFT, INRA and MRI whilst hedonic scales were used by AFT and BF. SF scales contained hedonic and quantitative categories for all attributes. The inclusion of hedonic descriptive and acceptability scales at each institute (SF substituted the common scale for their usual acceptability scale) is perhaps the most debatable feature. Less than fifteen assessors were used and it is commonly accepted that hedonic scales urge a response on the basis of the assessors' own immediate feelings, rather than attempting to elicit a detailed analysis of the attributes (Amerine *et al.*, 1965; AMSA, 1978). However, in total, there were fifty-one assessors and overall indications of acceptability are discussed below. Each institute grilled the steaks according to local practice using either time or temperature to determine the end point. Comparisons with other grilling methods (Tilgner, 1965) showed that the meat ranged from 'rare' to 'medium done' in the order INRA (grilling to 50 °C), BF and AFT (between 65 °C to 70 °C) and SF and MRI (about 75 °C).

It has long been recognised that the juiciness of steaks decreases with increase in end-point temperature (Cover *et al.*, 1957) but the five panels participating in this

study judged the steaks to be slightly juicy. This indicates that their assessments were based on their individual standard cooking methods and that each panel had a different reference for what was considered juicy. However, juiciness scores were poorly related between panels and were related no better between panels using similar end-point temperatures than between panels using widely different end-point temperatures. A similar poor interrelationship was found by Cross *et al.* (1978) in the USA where four panels judged the juiciness of beef steaks, using identical cooking and descriptive categories. The relatively small variation in juiciness in this and the American study would be expected to produce poor interrelationships between panels but differences in the perception or interpretation of juiciness cannot be ruled out. The latter is supported by comparing inter-relationships of attributes within panels. Despite the fact that variations in juiciness and tenderness were the same at each institute, the variations in one of those attributes accounted for by the other were 0, 18, 10, 20 and 45 % at MRI, SF, AFT, BF and INRA, respectively—i.e. their interrelationship increased inversely with the end-point temperature. A similar interrelationship between juiciness and tenderness was reported for rare broiled steaks but not in well done steaks (Cover *et al.*, 1957) and although the reason is not clear it is likely that some components of tenderness (e.g. softness, see Cover *et al.*, 1957) are associated with components of juiciness. There are two components of juiciness (Harries & MacFie, 1976); the initial (wetness) component varies less when tasted at 50 °C than when tasted at 22 °C, whilst the sustained component is unaffected (Caporaso *et al.*, 1978). Juiciness would then be expected to vary more at lower end-point temperatures but, although discrimination of meats for juiciness varied between these and the US panels (Cross *et al.*, 1978), it did not vary consistently with end-point temperature in this study.

Despite differences in end-point temperatures (and presumably testing temperature which affects flavour, Caporaso *et al.*, 1978), the overall judgements by the AFT, INRA and MRI panels were similar: moderate/weak beef flavour. Correlations among panels, however, were too low for the prediction of the flavour of individual animals or differences between sources. The degree of correlation between panels was not related to differences in end-point temperature. At AFT, use of hedonic descriptors, as expected, increased the variation between assessors but, considering all panels, discrimination between sources was governed mainly by the number of categories and the type of descriptor, rather than the use of—or lack of—hedonics. Those panels employing eight or eleven categories (AFT, INRA and SF) discriminated more than those using six or four categories (AFT, BF and MRI) and an extended scale (SF) including 'off flavour' categories produced the most discriminating panel, although this may have been fortuitous since SF stored the frozen steaks for the longest period.

Scales for tenderness were quantitative except that used at SF which contained hedonic descriptors. Use of the common eight-category quantitative scale did not affect discrimination and assessments using that scale correlated well with those

using the common scale. At SF, therefore, the quantitative nature of tenderness appears to be dominated by hedonic judgement. The variation between assessors at BF, INRA and SF was similar to that obtained in US panels (Cross *et al.*, 1978); in AFT and MRI panels variation was much larger.

Although correlations between panels for tenderness were high, they were generally lower than those found by Cross *et al.* (1978) between US panels using common cooking and assessment methods. In the present work differences in cooking between panels cannot entirely account for the lower correlations since coefficients were no higher between panels using similar end-point temperatures than those using temperatures differing widely. Whilst end-point temperature would be expected to have a large effect on tenderness (Hostetler *et al.*, 1976), panels gave similar assessment which, overall, was borderline between tough and tender. As with juiciness, the tenderness 'reference' depended on regional experiences. Similar conclusions have been deduced from comparisons of different muscles which, cooked domestically (rare broiled LD and well-done braised *M. biceps femoris*), were most tender (Cover *et al.*, 1957). Tenderness of different muscles responds differently to temperature (Hostetler *et al.*, 1976), but there is generally less variation at low temperature (60 °C) than at higher temperatures (80 or 100 °C). However, this was not the case in this comparison since assessors at INRA discriminated as well as assessors at MRI and AFT and therefore discrimination also seemed modified by experience. Caution should be exercised in comparing discrimination between panels because steaks were allocated sequentially and variation between animals differs according to anatomical position in the LD (Buchter, 1972; Hansen, 1973). However, variation between animals is greater around the 11th rib, the region from which steaks tasted at BF and AFT were derived. Larger variation in this region would produce an over-estimate of discrimination at BF and AFT but they would be still less discriminating than SF or INRA. Discrimination between meats is dependent on the aspect of a tenderness profile (Cross *et al.*, 1978) and different panels may assess different aspects. Connective tissue (Cross *et al.*, 1978) and chew count (Harries & MacFie, 1976) are distinguished subjectively from other tenderness aspects although all are related structurally (Dransfield & Rhodes, 1976).

Acceptability was determined largely by the wide variation in tenderness and there was little evidence that panels were biased in favour of beef from any particular origin or production method. Although the BF panel found German beef more acceptable than did the other panels, they found relatively little difference between sources overall. Much larger consumer panels and many more representative animals would be needed to substantiate this. In Denmark, half of the beef is derived from bulls, but these are exported; heifer and young cow beef, which nationally account for about 11 % and 38 %, respectively, of animals slaughtered, were chosen as representative of local consumption. Young cows were also chosen from France and the German Federal Republic where they represent 33 % and were contrasted

with bull beef, representing 18 % and 50 % of animals slaughtered, respectively. Bull beef represents 70 % and 33 % of production in Italy and Belgium, respectively. Bull beef was among the leanest (EAAP grade 1 to 4$^-$) whilst steers from the UK were among the fattest carcasses (grade 3 to 5$^-$). In the UK and Ireland about half the animals slaughtered are steers with 25 % heifers and 25 % cows. Because of that unbalanced sampling, only a limited number of comparisons could be made but breed, sex, age or carcass fatness were not major factors contributing to quality, which was influenced mainly by post-slaughter handling. On average, meat was aged for 8 days; that which was aged for 16 days produced the most tender meat whilst that aged for 2 to 4 days was among the toughest. The degree of toughness in twelve of the eighty steaks suggested that cold-shortening (Locker *et al.*, 1975) had occurred. Although electrical stimulation as a means of avoiding cold-shortening is being implemented in some abattoirs, its more widespread use in EEC countries, together with the adoption of ageing beef for at least 10 days at 1 °C, would improve quality overall and enable any pre-slaughter influences on eating quality to be realised.

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REFERENCES

AMERINE, M. A., PANGBORN, R. M. & ROESSLER, E. B. (1965). *Principles of sensory evaluation of food*, Academic Press, New York.

AMSA (1978). *Guidelines for cooking and sensory evaluation of meat*, Am. Meat Sci. Assn. Natl. Livestock and Meat Bd., Chicago.

ASTM COMMITTEE E-18 (1968). *Manual on sensory testing methods*, STP 434. Am. Soc. Testing and Materials, Philadelphia, USA.

BOCCARD, R., BUCHTER, L., CASTEELS, M., COSENTINO, E., DRANSFIELD, E., HOOD, D. E., JOSEPH, R. L., MACDOUGALL, D. B., RHODES, D. N., SCHON, I., TINBERGEN, B. J. & TOURAILLE, C. (1981). *Livestock Production Science*, **8**, 385.

BSI (1980). *BS 5929 Part 1*. British Standards Institute, London.

BUCHTER, L. (1972). *Symp. No. 2 'Meat chilling—Why and How?'*, ARC Meat Research Institute, Langford, Bristol.

CAPORASO, F., CORTAVARRIA, A. L. & MANDIGO, R. W. (1978). *J. Food Sci.*, **43**, 839.

COVER, S., BANNISTER, J. A. & KEHLENBRINK, E. (1957). *Food Res.*, **22**, 635.

CROSS, H. R., MOEN, R. & STANFIELD, M. S. (1978). *Food Technol.*, **32**(7), 48.

DE BOER, H., DUMONT, B. L., POMEROY, R. W. & WENIGER, J. H. (1974). *Livestock Production Science*, **1**, 151.

DRANSFIELD, E. & RHODES, D. N. (1976). *J. Sci. Food Agric.*, **27**, 483.

HAMM, R. (1976). In: *Seminar 'Criteria and Methods for Assessment of Carcass and Meat Characteristics in Beef Production Experiments'*. Commission for the European Communities, Brussels, p. 301.
HANSEN, L. J. (1973). *J. Food Sci.*, **38**, 286.
HARRIES, J. M. & MACFIE, H. J. H. (1976). *J. Food Technol.*, **11**, 449.
HOSTETLER, R. L., DUTSON, T. R. & CARPENTER, Z. L. (1976). *J. Food Sci.*, **41**, 421.
HOUWING, H. (1971). Organoleptical quality assessment of fresh fish. Review paper presented at the *European Fisheries Technologists Conference*, Torry Research Station, MAFF, Aberdeen.
HURWICZ, H. & FISCHER, R. G. (1954). *Food Technol.*, **8**, 391.
LOCKER, R. H., DAVEY, C. L., NOTTINGHAM, P. M., HAUGHEY, D. P. & LAW, N. H. (1975). *Adv. Food Res.*, **21**, 157.
PRELL, P. A. (1976). *Food Technol.*, **30**(11), 40.
RHODES, D. N., JONES, R. C. D., CHRYSTALL, B. B. & HARRIES, J. M. (1972). *J. Text. Studies*, **3**, 298.
TILGNER, D. J. (1965). *Fleischwirtschaft*, **45**, 1150.
WASSERMAN, A. E. (1979). *J. Food Sci.*, **44**, 6.