Meat Science **8** (1983) 79–92

Comparison of Chemical Composition of Meat Determined at Eight Laboratories

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(Received: 28 June, 1982)

Meat Science 0309-1740/83/0008-0079/$03·00

SUMMARY

Sixteen minced samples of lean beef M. semimembranosus *and* M. gracilis *were analysed for nitrogen, fat, moisture, collagen, ash and pH using recommended procedures in eight European Communities' (EC) meat research laboratories. Differences between replicate determinations within laboratories were often larger than suggested in reference methods although they were smaller than the differences between laboratories. Moisture and pH were determined most consistently, collagen least consistently.*

INTRODUCTION

Quality is difficult to define since it depends ultimately on subjective assessment. Instrumental and chemical measurements of quality are desirable as an objective basis for standardisation and labelling meat and meat products. The major chemical aspects of beef quality important to the consumer are connective tissue and fatness. Those characteristics, unlike organoleptic assessments, are readily analysable and determinations of fat in products have long been part of the enforcement of statutory meat content.

Recently, a Commission of European Communities' (CEC) Working Group (Boccard *et al.*, 1981) recommended that fat, moisture, nitrogen and collagen should form part of quality assessments in beef production experiments since they are components of texture and appearance. In determining those chemical criteria the CEC Working Group sought to recommend reference methods which are commonly used in Europe. Procedures were recommended for pH, fat, protein, moisture and hydroxyproline. Although the Group felt that tolerances within laboratories given by international and national standards were reasonable, they could not estimate the variations likely to occur between the eight laboratories comprising the Working Group.

Since the Group comprised representatives of European meat research institutes who were particularly interested in the quality of commercial animals from beef production trials, they decided initially to compare chemical determinations on unadulterated trimmed lean beef muscles.

MATERIALS

Eight 12-month old Galloway steers and eight 18- to 20-month old Charolais cross steers were kept in lairage with food and water for 48 to

72 h before slaughter in an abattoir in the south west of England approved for intracommunity trade.

After slaughter the carcasses were held at ambient temperature for 4 to 6 h and then placed in a chillroom operating between 7 and 10 °C. Twenty-four hours later, the carcasses were transferred to a chillroom at 1 °C. At this stage the deep leg temperatures ranged from 14 to 22 °C.

M. semimembranosus (Sm from Charolais crosses, samples 3, 4, 7, 8, 11, 12, 15 and 16) and *M. gracilis* (Gr from Galloway steers, samples 1, 2, 5, 6, 9, 10, 13 and 14) from both sides of each carcass were dissected and any surface connective tissue and insertions removed. In addition, fat was trimmed from the surface of the Sm. Left and right muscles from each animal were diced, mixed together and minced through a 4 mm mincing plate. The mince was then mixed, re-minced and re-mixed. Approximately 200 g sub-samples of mince from each muscle were packed in high density polythene screw topped pots or vacuum packed in Metathene bags and then frozen at −25 °C for 1 month.

The samples were transferred to boxes insulated with 5 cm thick polystyrene. On the day of transport, approximately 9·5 kg of 'dry ice' were placed in the insulated boxes for flights to Ireland, Belgium and The Netherlands and approximately 18 kg for flights to Germany, Denmark, Italy and France. All samples were kept frozen during transportation and transfers to laboratories were completed by road within 36 h.

METHODS

Chemical determination

Nitrogen was determined by the Kjeldahl method in which nitrogen is converted to ammonia and assayed by titration (ISO R937, 1969; Nordic Committee on Food Analysis, 1976).

Fat was determined on about 10 g of mince by the Soxhlet method for free fat content (ISO 1444, 1973; BS 4401 part 5, 1970) except at one laboratory where total fat, following hydrolysis with dilute mineral acid (BS 4401 part 4, 1970), using the Schmid-Bondzynski-Ratslaff (SBR) method (Nordic Committee on Food Analysis, 1974) was used.

Moisture was determined by drying to constant weight at 105 °C or lower temperatures under vacuum (BS 4401 part 3, 1970; ISO 1442, 1973).

Collagen was expressed as 7·14 × hydroxyproline determined colourimetrically following acid hydrolysis (ISO 3496, 1978; BS 4401 part 11, 1979; Nordic Committee on Food Analysis, 1974).

Ash, the residue after incineration (BS 4401 part 1, 1969) was determined at three laboratories.

The pH was determined directly by probe and on homogenates using an equal part of isotonic saline (Boccard *et al.*, 1981) or water (ISO 2917, 1974).

Estimating precision

Within each laboratory, the replicate values of each sample were normalised to a sample mean of zero. The standard deviation, pooling all normalised values (sixteen samples × the number of replicates) was calculated for each laboratory. Repeatability and reproducibility (BS 5497 part 1, 1979) were calculated across laboratories and tabulated with the mean for each sample as recommended in BS 5497.

Repeatability (r), is the value below which the difference between two determinations within a laboratory will occur with a probability of 95 % and $=2\sqrt{2\sigma_r^2}$, where σ_r^2 is the repeatability variance.

Reproducibility (R) is the value below which the difference between two laboratories will occur with a probability of 95 % and is $=2\sqrt{2}\sqrt{\sigma_L^2+\sigma_r^2}$, where σ_L^2 is the between-laboratory variance.

Dixon's test was used to identify 'stragglers' and/or 'statistical outliers' and Cochran's maximum variance test was used to determine homogeneity of variance (BS 5497, 1979).

RESULTS

Nitrogen

Overall, nitrogen was 3·4 % of the wet weight (Table 1). Individual muscles varied from 3·2 to 3·7 % (Table 2) but there was little difference between Sm and Gr which had nitrogen (fat-free) values of 3·6 and 3·5 %, respectively.

The standard deviation between replicates within each laboratory (Table 1) averaged 0·05 % and varied from 0·02 at laboratory F to 0·09 % at laboratories C and G. Repeatability, which ranged from 0·07 (sample

TABLE 1

Chemical Determinations at Eight Laboratories

Values are the overall mean of sixteen muscles with the number of replicate determinations indicated. Within laboratories, the standard deviation (SD) was calculated from muscle replicate assays after normalising each of the sixteen sample means to zero. Measurement of pH at laboratory C was by probe (C1) and in homogenates (C2)

	Laboratory							
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Nitrogen								
Mean	3·4	3·4	3·4	3·5	3·4	3·5	3·3	3·3
Replicates	2	1	3	2	2	2	4	1
SD × 100	4·2		8·8	3·0	2·4	2·3	9·3	
Fat								
Mean	3·5	4·0	4·0	3·5	3·7	4·0		
Replicates	2	1	3	2	2	2		
SD × 10	1·7		5·2	2·4	2·0	5·9		
Moisture								
Mean	74·2	74·4	74·3	74·5	74·4	73·8	74·2	
Replicates	2	1	3	2	2	1	2	
SD × 10	2·7		2·6	2·4	3·5		1·1	
Collagen								
Mean	1·1	1·7	1·1	1·2			1·2	
Replicates	2	2	3	1			2	
SD × 100	8·7	2·4	16·0				2·8	
Ash								
Mean		0·9	1·1					1·3
Replicates		1	3					1
SD × 100			4·0					
pH		C1	C2	D	E	F		H
Mean		5·5	5·6	5·6	5·5	5·6		5·6
Replicates		3	3	1	1	1		1
SD × 100		2·4	1·5					

1) to 0·45 (sample 2), and reproducibility, which ranged from 0·2 (sample 9) to 0·54 % (sample 5), were unrelated to sample mean (Table 2). The averages over all samples were 0·17 and 0·28 %, respectively.

Fat

Overall, the fat content averaged 3·8 % of the wet weight and varied from 2 to 6·4 % (Table 3). Laboratory means varied from 3·5 to 4·0 % (Table 1)

TABLE 2
Nitrogen Determination

Values are the mean (number of replicates in Table 1) as a percentage by mass for each of sixteen samples from eight laboratories (A to H). Excluding assays from laboratories B and H (which did not submit replicate determinations) and certain individual rejected values (see footnote), the mean (m) over all replicate values, repeatability (r) and reproducibility (R) were calculated for each sample

	Laboratory										
	B	*H*	*A*	*D*	*E*	*C*	*F*	*G*	m	r	R
1	3·23	3·17	3·33	3·25	3·24	3·31	3·24	3·05[a]	3·28	0·06	0·13
2	3·31	3·28	3·47	3·45	3·41	3·12	3·35	3·25	3·32	0·40	0·50
3	3·61	3·66	3·58	3·76	3·72	3·68	3·66	3·52	3·64	0·31	0·35
4	3·64	3·52	3·56*	3·76	3·69	3·65	3·70	3·61	3·67	0·20	0·23
5	3·25	3·09	3·31	3·26	3·22	3·21	3·68[a]	3·14	3·21	0·13	0·53
6	3·25	3·20	3·29	3·41[a]	3·29	3·23	3·26	3·27	3·28	0·29	0·28
7	3·56	3·58	3·62	3·70	3·59	3·57	3·55	3·34	3·53	0·20	0·42
8	3·61	3·41	3·58	3·75	3·67	3·57	3·65	3·55	3·61	0·12	0·23
9	3·17	3·07	3·22	3·28	3·20	3·24	3·13	3·13	3·19	0·11	0·19
10	3·24	3·04	3·17	3·37	3·29	3·19	3·36	3·22	3·25	0·12	0·25
11	3·41	3·26	3·43	3·56	3·47	3·48	3·44	3·45	3·47	0·29	0·25
12	3·52	3·30	3·58	3·76	3·67	3·52	3·75	3·58	3·63	0·15	0·30
13	3·18	3·01	3·23	3·28	3·16	3·07	3·20	3·20	3·17	0·12	0·22
14	3·33	3·57	3·34	3·36	3·42	3·37	3·54	3·27	3·37	0·11	0·27
15	3·29	3·14	3·31	3·43	3·34	3·41	3·38	3·42	3·39	0·15	0·17
16	3·48	3·41	3·42	3·60	3·54	3·50	3·57	3·42	3·50	0·11	0·23

[a] = Sample determination rejected by Dixon's test.
* = One determination only which was not included in calculations of m, r and R.

and Sm from Charolais crosses (2·9 %) was leaner than Gr from Galloway (4·7 % fat). The total fat contents determined at laboratory E were similar to free fat contents determined at the other laboratories.

The standard deviation between replicates (Table 1) varied from 0·2 at A (free fat) and E (total fat) to 0·6 % at F. Repeatability and reproducibility were unrelated to the sample means (Table 3); the averages over all samples were 0·97 and 1·5 %, respectively. Reproducibility of sample 13 was particularly poor, due mainly to the very high value at laboratory C (Table 3).

Moisture

Means of laboratories varied from 73·8 to 74·5 % (Table 1). The moisture

TABLE 3

Fat Determination

Values are the mean (number of replicates in Table 1) as a percentage by mass for each of sixteen samples from six laboratories (A to F). Excluding assays from laboratory B (which did not submit replicate determinations) and certain individual rejected values (see footnote), the mean (m) over all replicate values, repeatability (r) and reproducibility (R) were calculated for each sample

	Laboratory								
	B	*A*	*D*	*E*	*C*	*F*	m	r	R
1	3·48	2·79	2·55	2·89	2·98	3·48	2·94	0·40	0·97
2	4·58	4·50	4·40	4·09	4·17	7·29[a]	4·28	0·77	0·78
3	2·57	1·95	1·65	1·65	1·89	2·18	1·87	0·43	0·68
4	2·93	2·19	2·40	2·24	2·27	2·90	2·39	0·62	0·92
5	3·19	2·43	2·75	2·90	3·06	3·38	2·92	0·61	1·07
6	5·68	5·24	4·75	5·61	6·92[b]	5·70	5·64	0·98	2·38
7	2·19	2·20	1·85	1·96	1·85[b]	2·41	2·05	0·61	0·82
8	3·07	2·35	2·50	2·82	2·38	3·49	2·68	0·58	1·39
9	5·40	5·21	6·65	5·41	5·69	4·83	5·57	2·52	2·63
10	5·76	6·18	6·25	6·21	7·08	6·68	6·53	1·35	1·55
11	3·69	3·16	3·25	3·37	3·92	3·00	3·39	1·68	1·65
12	4·03	2·92	2·70	3·25	3·39	3·54	3·18	0·84	1·14
13	5·50	5·52	5·50	5·59	8·86[b]	6·28	6·35	2·19	4·36
14	3·85	2·99	2·55	3·09	2·76	3·23	2·91	0·65	0·81
15	3·78	3·10	2·90	3·61	3·19	3·26	3·21	0·53	0·59
16	3·93	3·23	2·90	3·73	2·60	3·67	3·17	0·81	1·56

[a] = Sample determination rejected by Dixon's test.

[b] = Mean after rejecting, by Cochran's test, one replicate determination.

content of muscles varied from 73·0 to 76·0 % and averaged 74·3 % in Sm and Gr muscles (Table 4).

The standard deviation between replicates (Table 1) varied from 0·1 at laboratory G to 0·4 % at laboratory E. Repeatability, which varied from 0·2 (sample 6) to 1·0 % (sample 9) and reproducibility, which varied from 0·3 (sample 6) to 2·1 % (sample 9), were unrelated to the sample means (Table 4) and averaged 0·50 and 0·95 %, respectively.

Collagen

Collagen was determined at five laboratories but the assays obtained at laboratory B were consistently higher (on average 0·5 %) than assays from

TABLE 4

Moisture Determination

Values are the mean (number of replicates in Table 1) as a percentage by mass for each of sixteen samples from seven laboratories (A to G). Excluding assays from laboratories B and F (which did not submit replicate determinations) and certain individual rejected values (see footnote), the mean (m) over all replicate values, repeatability (r) and reproducibility (R) were calculated for each sample

	Laboratory									
	B	*A*	*D*	*E*	*C*	*F*	*G*	m	r	R
1	75·80	76·04	76·45	76·16	75·04	75·42	76·15	75·88	0·54	0·74
2	73·54	73·60	74·15	74·08	73·90	73·51	73·73	73·89	0·89	0·90
3	73·18	74·04	74·80	74·63	74·66	73·69	74·39	74·52	0·48	0·89
4	74·13	74·38	74·20	74·33	74·51	73·67	74·14	74·33	0·53	0·59
5	76·30	76·04[a]	76·00	75·90	76·00	75·56	75·92	75·96	0·34	0·29
6	73·81	73·22	73·85	72·80	73·33[b]	72·82	73·04	73·25	0·16	1·11
7	74·85	74·38	74·85	75·28	75·02	74·62	75·00	74·92	0·31	0·93
8	74·05	74·01	74·15	74·12	74·19	73·86	73·97	74·10	0·67	0·56
9	74·57	73·76	72·90	74·37	72·89	74·18	74·10	73·54	0·98	2·09
10	73·76	72·95	73·45	72·66	72·66	71·14	72·72	72·87	0·65	1·05
11	74·64	74·27	74·15	74·47	74·01	74·19	74·61	74·28	0·44	0·78
12	73·60	73·26	73·80	73·59	74·01	73·07	73·33	73·64	0·54	1·01
13	74·20	73·55	73·85	74·26	74·25	72·55	74·04	74·01	0·28	0·87
14	75·08	74·61	75·55	75·04	75·05[b]	73·86	74·79	75·01	0·52	1·07
15	75·22	74·76	75·60	75·51	74·70	74·48	73·77	74·85	0·38	2·03
16	73·64	73·60	74·20[a]	73·71	73·71	74·39	73·60	73·66	0·35	0·31

[a] = Sample determination rejected by Dixon's test.

[b] = Mean after rejecting, by Cochran's test, one replicate determination.

the other laboratories (Table 1). Collagen content (Table 5) varied from 0·7 to 1·5%; Gr from Galloways (1·4%) having more than Sm from Charolais crosses (0·9%).

The greatest variation between replicates (Table 1) was found at laboratory C with a standard deviation of 0·16%, and the least variation at laboratory B with a standard deviation of 0·02%. Repeatability, which varied from 0·02 (sample 1) to 0·68% (sample 5) and reproducibility, which varied from 0·12 (sample 13) to 1·3% (sample 12), were unrelated to the sample means (Table 5) and averaged 0·17 (excluding sample 5 which was unusually variable) and 0·67%, respectively. Excluding laboratory B, the repeatability value (r) was 0·22 and the reproducibility (R) was 0·42%.

TABLE 5

Collagen Determination

Values are the mean (number of replicates in Table 1) as a percentage by mass for each of sixteen samples from five laboratories. Excluding assays from laboratory D (which did not submit replicate determinations) and certain individual rejected values (see footnote), the mean (m) over all replicate values, repeatability (r) and reproducibility (R) were calculated for each sample

	Laboratory							
	B	*A*	*D*	*C*	*G*	m	r	R
1	1·89	1·36	1·64	1·24	1·44	1·46	0·16	0·81
2	1·78	1·48	1·43	1·02[b]	1·46	1·44	0·05	0·89
3	1·30	0·75	0·64	0·86	0·82	0·92	0·30	0·71
4	1·50[a]	0·80	0·93	0·82	0·75	0·79	0·10	0·13
5	2·43[a]	1·38	1·64	1·22	1·40	1·32	0·68	0·59
6	1·89	1·27	1·64	1·43[a]	1·57	1·58	0·07	0·88
7	1·07	0·67	0·57	0·75	0·64	0·78	0·06	0·53
8	1·33	0·88	0·71	0·82	0·92	0·97	0·19	0·66
9	1·67[a]	1·38	1·21	1·39	1·35	1·38	0·33	0·26
10	1·56	1·22	1·36	1·12	1·22	1·26	0·22	0·57
11	1·42	1·00	0·93	1·36	1·12	1·24	0·18	0·57
12	1·96	1·12	1·29	0·94	1·03	1·23	0·31	1·33
13	1·94[a]	1·34	1·36	1·39[b]	1·42	1·38	0·07	0·12
14	2·00	1·58	1·64	1·21	1·54	1·54	0·09	0·95
15	1·55	0·96	1·07	1·16	1·09	1·19	0·30	0·72
16	1·27	0·78	0·64	1·50[b]	0·84	1·10	0·21	0·99

[a] = Sample determination rejected by Dixon's test.

[b] = Mean after rejecting, by Cochran's test, one replicate determination.

Ash

Ash, determined at only three laboratories, varied little between muscles and averaged 1·1% and ranged from 0·9 at laboratory B to 1·3% at laboratory H. Values obtained at laboratory B were consistently lower than those at laboratory H and consistently higher than those at laboratory C (Table 6).

Replicate determinations were submitted from laboratory C only. The standard deviation between replicates (Table 1) was 0·04%. Ash, protein,

TABLE 6
Ash Determination
Values are the mean (number of replicates in Table 1) as a percentage by mass, for each of sixteen samples together with the mean ($\bar{x}$) of the three laboratory values

	Laboratory			
	B	*C*	*H*	$\bar{x}$
1	0·98	1·01	1·2	1·06
2	0·84	1·01	1·1	0·98
3	0·97	1·18	1·2	1·12
4	0·96	1·12	1·3	1·13
5	0·88	1·03	1·3	1·07
6	0·83	1·02	1·2	1·02
7	0·98	1·29	1·4	1·22
8	0·95	1·17	1·3	1·14
9	0·89	0·98	1·2	1·02
10	0·93	1·06	1·6	1·20
11	0·90	1·11	1·2	1·07
12	0·99	1·19	1·1	1·09
13	0·86	0·97	1·2	1·01
14	0·93	1·11	1·2	1·08
15	0·94	1·03	1·4	1·12
16	0·91	1·12	1·1	1·04

fat and moisture totals for each sample averaged 100·5% with a standard deviation of 0·3 at laboratory B and 100·3% and 0·5 respectively, at laboratory C.

pH

Both reference methods were used in laboratory C (Table 1) where the homogenates (C2) gave more consistent results (standard deviation, 0·015 units) than were given by the probe directly (C1, standard deviation, 0·024 units). Other laboratories supplied mean values only (Table 7). The pH of the samples varied from 5·4 to 5·7 (Table 7) and laboratory means varied from 5·5 to 5·6 (Table 7). Of 240 paired differences, 29 (12%) were greater than 0·15 units and 12 (5%) were equal to, or greater than, 0·2 units (Table 7).

TABLE 7
pH Determination
Values are the mean (number of replicates in Table 1) for each of sixteen samples together with the mean ($\bar{x}$) of the five laboratory values. Means for laboratory C using probe method (C1) and homogenates in isotonic saline (C2)

	Laboratory						
	C1	*C2*	*D*	*H*	*E*	*F*	$\bar{x}$
1	5·67	5·70	5·6	5·6	5·60	5·75	5·65
2	5·38	5·38	5·5	5·6	5·45	5·35	5·44
3	5·53	5·54	5·6	5·7	5·49	5·70	5·59
4	5·64	5·64	5·7	5·6	5·57	5·65	5·63
5	5·67	5·70	5·7	5·7	5·60	5·50	5·65
6	5·37	5·45	5·6	5·6	5·45	5·30	5·46
7	5·50	5·61	5·6	5·5	5·51	5·65	5·56
8	5·52	5·60	5·6	5·6	5·52	5·70	5·59
9	5·59	5·70	5·7	5·6	5·55	5·65	5·63
10	5·31	5·41	5·6	5·7	5·51	5·65	5·53
11	5·60	5·60	5·7	5·7	5·56	5·70	5·64
12	5·51	5·61	5·6	5·6	5·52	5·65	5·58
13	5·54	5·69	5·7	5·7	5·57	5·70	5·65
14	5·35	5·60	5·6	5·5	5·57	5·65	5·55
15	5·60	5·68	5·7	5·6	5·55	5·70	5·64
16	5·56	5·60	5·7	5·7	5·51	5·65	5·62

CONCLUSIONS

In animal production experiments relatively small variations in fat and connective tissue are important since they can affect quality to the consumer and the market value of the meat. In these comparisons fat content ranged from 2 to 6% and connective tissue from 0·7 to 1·5% which is typical for large hindquarter muscles used commonly for quality assessment.

All laboratories used the same agreed analytical procedures (Boccard *et al.*, 1981) based on reference methods which recommend that duplicate determinations be carried out followed by a further analysis when a specified tolerance is exceeded. In this trial, laboratories usually made duplicate determinations, laboratory C did three and laboratory G, four,

for nitrogen. Differences between replicate determinations varied according to the laboratory and often exceeded the recommended value. Analysts rarely made further determinations but when they did they appeared to do so on experience rather than to meet a specified tolerance.

The precision of measurements within and between laboratories varied between samples but was unrelated to the sample means. Within the range of composition studied, therefore, the precision is best quoted as an absolute value, rather than as a proportion of the mean, as suggested for hydroxyproline analyses (ISO 3496, 1978) and for general use (Boccard *et al.*, 1981).

Precision for nitrogen determination varied fourfold between laboratories and, overall, 95% of replicate determinations differed by up to 0·2%. Therefore, although some laboratories obtained the precision (the difference between two determinations carried out simultaneously or in rapid succession by the same analyst) of 0·1% given by the reference methods (ISO R937, 1969; BS 4401 part 2, 1969), the overall level of precision was half of that. Variation between laboratories was 1·7 times that within laboratories; 95% of determinations differing by up to 0·3%. Using all 128 determinations (eight laboratories × sixteen samples), the nitrogen (fat free) value averaged 3·53%, similar to the 3·55% recommended for general use, although the range observed here (3·3 to 3·8%) was less than that (3·0 to 4·5%) found in beef from a wide variety of sources (Analytical Methods Committee, 1963).

The precision of fat determination within laboratories varied threefold between laboratories. Overall, determinations differed by up to 1% which is twice the variation suggested in reference methods (BS 4401 parts 4 & 5, 1970; ISO 1444, 1973). Determinations in different laboratories differed by up to 1·5%.

Moisture was determined consistently within laboratories; overall, replicates differed by less than 0·5% which is the difference suggested in reference methods (BS 4401 part 3, 1970; ISO 1442, 1973). Variations between laboratories were also small—less than 1%. Since moisture content is most susceptible to conditions and length of storage, its accurate determination suggests that the sampling and distribution procedures were good.

Collagen determination was the least precise analysis. Ninety-five per cent of replicate determinations differed by up to 0·2%—well above the suggested value of 0·06% (5% of the 1·26 mean value; ISO 3496, 1978). Variation between the five laboratories which determined collagen was

0·7% (although this was reduced to 0·4% when one laboratory was eliminated) in meat with an average content of 1·3% of wet mass. Laboratory C had the most variable assays but the means were similar to those obtained at laboratories A, D and G whereas laboratory B had the most consistent assays but the means were 0·5% higher than at other laboratories.

Replicate values for pH measured by probe and in homogenates at laboratory C were often within 0·15 units—the suggested variation (ISO 2917, 1974)—and 95% of the values across laboratories were within 0·2 units (Table 7).

This study, although limited to sixteen beef muscles and eight laboratories, demonstrated clearly that on minced beef muscle experienced analysts often presented more variable replicate results than reference methods would suggest and that even greater variation occurred between laboratories. The accurate determination of moisture content suggested that the difference in the other analyses could not be ascribed to uncontrolled variation between sub-samples and must therefore be attributed to differences between laboratories. Such estimates of variation obtained in practice are equally, if not more, important than the reference values and should be taken into account when formulating standards for meat and meat products.

ACKNOWLEDGEMENTS

The work was supported by the Commission of European Communities, Directorate General for Agriculture, Division for the Co-ordination of Agricultural Research, 200 rue du Roi, 1049 Brussels, Belgium, as part of a programme on beef production.

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