

Chemical Characterisation of Mechanically Recovered Meats

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Forty samples of various types of mechanically recovered meats (MRM) were analysed for their chemical composition including moisture, fat, protein, ash, bone content, fatty acids, sterols, pH, hydroxyproline and trace element content. The MRM samples examined varied greatly in their chemical composition, and often differed significantly from equivalent hand-deboned meats. The significance of the data presented is considered.

The final figure for total UK meat production in 1984 is expected to be about 3.83 million tonnes carcase weight, comprising 60 per cent. of red meat (beef, veal, pork and lamb) and 40 per cent. of fowl (poultry, broiler and turkey)¹. Mechanical recovery of meat following hand deboning operations gives an additional carcase yield of up to 4 per cent. for red meat and 15 per cent. for fowl, making obvious the attraction of such processes for the meat product manufacturer. In 1982 the value of potentially separable mechanically recovered meat from red-meat carcasses alone was being put at around £9M². Mechanically recovered meat is already being incorporated in traditional comminuted meat products such as sausages, pies and burgers, as well as soups, infant foods and special diets for the disabled. This usage is likely to increase until the economic recovery of MRM from UK produced bones has been maximised (at the moment the importation of bones for processing is prohibited).

Most of the analytical data on MRM composition have been published in the USA³ where continuous auger-type machines, such as the Beehive, which process pre-ground bone material, are used rather than the press-type Protecon and Hydrau machines favoured in the UK which can handle batches of quite large intact bones⁴. Other major differences between the two recovery processes have been considered in some detail elsewhere^{4,5}.

Relatively little information is available concerning the composition of MRMs produced in the UK^{5,6} or other EEC countries^{7,8}. In this study a total of 40 samples of mechanically recovered meat were examined. Of these, 29 (numbered 1-29) were obtained through Trading Standards Officers or directly from meat product manufacturers. The remaining 11 (numbered 30-40) came from a major specialist supplier of MRM to the UK meat industry. The amount of background information available varied according to the source of the samples, although in most instances sufficient detail was available to identify the origin of the bones and the type of processing machinery employed. At the commencement of the study only samples 30-40 could be guaranteed as

"authentic", that is, containing no foreign species nor "added water". However, the authors had no reason to suspect that any of the other samples collected were not produced to a similar standard.

Each sample of MRM was analysed for proximate composition, calcium, magnesium and iron contents. Samples numbered 30–40 whose histories were known more exactly (see Table 1) were subjected to additional analyses for pH, hydroxyproline, fatty acid isomers, sterols, bone content, copper, manganese, zinc, sodium, potassium and phosphorus. Microscopical examinations were carried out on each type of MRM.

Experimental

Ash, moisture, fat and L(-)-hydroxyproline were determined in duplicate according to BS:4401 Parts 1, 3, 4 and 11 respectively⁹.

Total nitrogen was determined in duplicate by Kjeldahl distillation using Tecator Kjeltac system 1003 (manual titration)^{10a,11} or model 1030 with automatic titration¹². Nitrogen recoveries obtained with both systems were checked regularly against a secondary standard wheatflour and periodically with ammonium sulphate and glycine.

pH values were measured in duplicate on each of two sample portions according to BS:4401 Part 9 using a glass electrode and a pH meter with automatic temperature correction facility at a temperature of 24–25°C⁹.

Bone content was determined gravimetrically following suspension and comminution of the sample in carbon tetrachloride¹³.

Calcium, copper, iron, magnesium, manganese and zinc were determined by inductively coupled plasma optical emission spectroscopy (ICP-OES) using an ARL 137 ICPQ system¹⁴.

Sodium and potassium were analysed by atomic absorption spectrometry (AAS) using a Perkin Elmer AA spectrophotometer model 403¹⁵.

Phosphorus was determined colorimetrically using a Technicon Auto-Analyser system^{10b,16}. All inorganic constituent determinations were checked against a standard reference material (NBS liver 1577)¹⁷.

Fatty acid isomers were analysed as their methyl esters by capillary column gas chromatography on a 50 m glass WCOT column coated with Reoplex 400 at a temperature of 175°C^{10c,18}.

Sterols were determined as their silyl ether derivatives by capillary column gas chromatography on a 25 m glass WCOT column coated with OV17 at a temperature of 250°C using betulin as internal standard^{10d,19}.

Microscopical examinations were carried out on 10 µm thick sections cut using a rotary retracting microtome in a cryostat cabinet at -20°C from small blocks of MRM previously frozen in liquid nitrogen. Sections taken from each sample were stained with toluidine blue to demonstrate general morphology²⁰, and with Carazzi's haematoxylin²¹, sirius red F3BA²², and alizarin red S²¹ to demonstrate haemopoietic bone marrow, collagenous connective tissues and bone fragments respectively.

Results

PRODUCTION OF MRM SAMPLES 30-40

Table I shows the operating parameters for the Protecon MRS 30 and MRS 60 machines used to produce MRM samples 30-40. In general the conditions represent an empirically determined compromise intended to maximise yield while avoiding a significant rise in temperature and minimising inclusions of excess fat, fragments of bone, connective tissue and bone marrow. There are three main variables; the pressure applied, the time of pressing and the stroke length, the latter being a measure of the amount of material pressed at any one time. For example, higher pressures and longer pressing times than normal are used for the recovery of duck MRM from neck bones because of the toughness of the neck tissues whereas lower pressures are used for recoveries of veal and cooked chicken MRM because of the softness of the associated bones and connective tissues. Recovery of MRM from hard boned carcasses such as pork and venison are carried out using longer stroke lengths which help regulate any temperature rise. The operating conditions shown in Table I are used to give a premium product suitable for resale as a raw ingredient and may not be typical of "end-of-line" recovery operations.

TABLE I
PRODUCTION CHARACTERISTICS OF MECHANICALLY RECOVERED MEAT
SAMPLES 30-40

Sample No. and type	Age and type of bones	Pressing time <i>s</i>	Stroke length*	Pressure <i>atm</i>
30 Turkey	5 months, bodies	4.5	2.5	240
31 Chicken	10-12 weeks, frames	4.5	2.5	240
32 Chicken	10-12 weeks, backs	4.5	2.5	240
33 Chicken, cooked	10-12 weeks, bodies	4.5	2.5	210
34 Duck	10 weeks, necks	7.5	3.5	250
35 Pork	5 months, chins, neck and breast	4.5	4.5	210
36 Lamb	3-4 months, ribs and necks	4.5	2.5	230
37 Lamb, semi-lean	3-4 months, belly end of ribs	4.5	2.5	230
38 Beef	18-24 months, forequarter	4.5	2.5	230
39 Veal, heavy	3 months, forequarter	4.5	2.5	200
40 Venison, wild	forequarter	4.5	4.5	225

* Machine setting.

PROXIMATE ANALYSES AND HYDROXYPROLINE CONTENTS

For the 40 samples of MRM analysed the mean figure for "total analysis", i.e. moisture + ash + fat + protein ($N \times 6.25$), was 99.5 per cent. ($s = 1.8$ per cent.), Tables II and III. As would be expected, fat and moisture contents were inversely related, with their sum consistently totalling between 80 and 90 per cent. of the total sample weight (mean = 84.3 per cent., $s = 2.8$ per cent.).

Fat contents of the MRM samples examined varied between 5 and 50 per cent. with beef MRM having the highest average fat content at 33.6 per cent. ($s = 8.4$ per cent., $n = 11$) and turkey MRM the lowest at 6.5 per cent. ($s = 2.3$ per cent., $n = 13$). Pork and chicken MRM were intermediate with average fat contents of 19.8 per cent. ($s = 6.7$ per cent., $n = 5$) and 17.5 per cent. ($s = 8.5$ per cent., $n = 5$) respectively. Chicken MRM samples showed the widest range of fat contents

TABLE II
ANALYTICAL COMPOSITION OF MECHANICALLY RECOVERED MEAT SAMPLES 1-29

Machine	Bones	Mois- ture	Fat	Ash	N	N × 6.25	Metals			DFM* per cent.	Total† meat per cent.	
		per cent.					Ca	Mg mg/kg	Fe			
Pork												
1	Protecon	ribs	63.1	19.1	1.1	2.61	16.3	784	144	12	75.7	94.8
2	Hydrau	no hock	61.1	22.3	1.0	2.50	15.6	440	75	10	72.5	94.8
3	Protecon	no marrow	56.0	29.9	0.9	2.22	13.9	697	155	46	64.3	94.2
4	Protecon	shoulder	67.2	13.4	1.1	2.48	15.5	794	152	38	71.9	85.3
Beef												
5	Hydrau	no marrow	54.0	37.6	0.9	1.92	12.0	756	59	26	54.1	91.7
6	Protecon	no marrow	51.5	32.2	1.1	2.15	13.4	1248	79	20	60.6	92.8
7	Protecon	no marrow	56.2	32.5	1.1	2.13	13.3	1462	149	44	60.0	92.5
8	Protecon	no marrow	59.6	23.4	1.3	2.25	14.0	1860	140	99	63.4	86.8
9	Beehive	no marrow	46.7	37.8	2.8	1.82	11.4	7966	201	83	51.3	89.1
10	Beehive	no marrow	39.6	48.8	2.6	1.52	9.5	7718	205	44	42.8	91.6
11	Beehive	no marrow	44.5	38.6	2.8	1.86	11.6	7942	202	71	52.4	91.0
12	Beehive	no marrow	46.4	40.5	2.6	1.86	11.6	7337	198	78	52.4	92.9
13	Protecon	?	51.5	33.0	1.0	2.13	13.3	1887	160	27	60.0	93.0
14	Protecon	?	60.7	21.1	1.1	2.54	15.9	1876	168	54	71.5	92.6
Chicken												
15	Protecon	backs	60.4	23.4	0.7	2.27	14.2	214	132	13	63.1	86.4
16	Protecon	necks	79.8	7.1	0.7	2.04	12.8	291	149	33	56.7	63.8
17	Protecon	necks	76.0	11.3	0.7	2.21	13.8	839	161	36	61.4	72.7
Turkey												
18	Protecon	necks	81.7	4.5	0.5	1.98	12.4	144	127	11	56.6	61.0
19	Protecon	necks	79.0	5.2	0.4	2.52	15.7	166	134	15	72.0	77.2
20	Protecon	all	79.2	6.7	0.6	2.03	12.7	188	152	18	55.6	62.3
21	Protecon	all	76.6	8.4	0.7	2.24	14.0	160	156	17	61.4	69.7
22	Protecon	all	78.7	6.0	0.7	2.26	14.1	278	168	20	61.8	67.8
23	Protecon	all	78.3	5.4	0.6	2.14	13.4	188	146	16	58.7	64.1
24	Protecon	all	77.6	5.4	0.7	2.51	15.7	158	172	17	68.8	74.1
25	Protecon	all	79.1	6.6	0.7	2.18	13.6	180	157	17	59.7	66.4
26	Protecon	all	77.7	4.1	0.7	2.29	14.3	172	165	20	62.7	66.8
27	Protecon	all	79.8	6.2	0.6	2.21	13.8	165	153	17	60.5	66.7
28	Protecon	all	72.6	5.6	0.7	2.34	14.6	178	162	14	64.0	69.6
29	Protecon	all	79.3	6.8	0.6	2.19	13.7	202	153	18	60.1	66.8

* "DFM" is an abbreviation for de-fatted meat. This is calculated from the equation $DFM = (100 \times \text{Nitrogen})/N_f$ where N_f is the appropriate "nitrogen factor" for the sample; this is a pre-determined value for the nitrogen content of the sample-type expressed on a fat-free basis. In Tables II, III and VIII the nitrogen factors used to convert analytical nitrogen into raw defatted meat were as follows: Pork samples 1-4 and 35, 3.45; Beef samples 5-14 and 38, 3.55; Chicken samples 15-17 and 31-33, 3.60; Turkey (necks) samples 18-19, 3.50; Turkey (all bones) samples 20-30, 3.65; Duck sample 34, 3.31; Lamb samples 36 and 37, 3.59; Veal sample 39, 3.35 and Venison sample 40, 3.59. References: 10e, 24, 25.

† Total meat = de-fatted meat + fat.

TABLE III

PROXIMATE COMPOSITION OF MECHANICALLY RECOVERED MEAT SAMPLES 30-40

Sample	Moisture	Fat	Ash	N	N × 6.25	DFM*	Total†
	per cent.					per cent.	meat per cent.
30 Turkey	70.3	13.1	0.7	2.23	13.9	61.1	74.2
31 Chicken (frames)	65.1	17.8	0.8	2.56	16.0	71.1	88.9
32 Chicken (bodies)	57.1	27.9	0.7	2.24	14.0	62.2	90.1
33 Chicken (cooked)	47.9	27.7	0.6	3.67	22.9	101.9	129.6
34 Duck	76.0	5.5	0.9	2.66	16.6	80.4	85.9
35 Pork	69.3	14.3	1.3	2.38	14.9	69.0	83.2
36 Lamb	63.8	20.1	1.0	2.58	16.1	71.7	91.8
37 Lamb "semi-lean"	40.9	46.5	0.5	1.73	10.8	48.1	94.6
38 Beef	59.9	23.6	1.3	2.37	14.8	66.8	90.4
39 Veal	61.5	23.2	1.0	2.45	15.3	73.1	96.3
40 Venison	69.0	13.6	0.9	2.55	15.9	71.2	84.8

*† See Table II.

TABLE IV

MINERAL COMPOSITION OF MECHANICALLY RECOVERED MEAT SAMPLES 30-40

Sample	Mineral composition mg/kg							
	Ca	Cu	Fe	Mg	Mn	Zn	Na	K
30 Turkey	411	0.60	25.1	126	0.18	22.7	635	1541
31 Chicken frames	383	0.31	22.0	173	0.24	12.6	864	2403
32 Chicken bodies	243	0.38	16.4	146	0.24	11.8	791	2073
33 Chicken cooked	340	0.25	25.9	127	0.15	47.7	914	1701
34 Duck	275	0.35	21.4	164	0.17	34.4	1050	2562
35 Pork	1739	1.10	56.5	173	0.11	21.6	1337	2469
36 Lamb	721	0.66	42.1	167	0.11	34.1	1032	2506
37 Lamb "semi-lean"	235	0.00	15.7	110	0.03	21.4	604	1781
38 Beef	1061	0.37	118	143	0.07	26.6	1349	1837
39 Veal	1112	0.68	34.2	146	0.05	24.7	1217	2046
40 Venison	1290	0.82	60.0	163	0.20	41.1	803	1738

TABLE V

pH, BONE, HYDROXYPROLINE, AND CHOLESTEROL IN MECHANICALLY RECOVERED MEAT SAMPLES 30-40

Sample	pH	Bone content	Hydroxy proline	Cholesterol content
		per cent.		mg/100g
30 Turkey	6.50	0.11	0.06	124
31 Chicken (frames)	6.40	0.17	0.13	164
32 Chicken (bodies)	6.35	0.04	0.24	165
33 Chicken (cooked)	6.40	0.26	0.84	300
34 Duck	6.60	0.02	0.18	142
35 Pork	6.70	0.60	0.08	209
36 Lamb	6.25	0.12	0.12	257
37 Lamb "semi-lean"	6.30	0.04	0.12	96
38 Beef	6.65	0.48	0.11	252
39 Veal	6.30	0.17	0.16	184
40 Venison	6.40	0.33	0.14	169

varying by a factor of four from 7.1 per cent. up to 27.9 per cent. reflecting the proportion of skin, and its associated adipose layer, attached to the carcasses used for processing²³.

Fat-free moisture contents of red meat MRM (78 per cent.) and poultry MRM containing no added water (79 per cent.) were slightly higher (2–4 per cent.) than for equivalent samples of lean hand deboned meats (HDM)^{24,25}.

Ash figures obtained from the analysis of red meat MRM were generally higher than those found in comparable HDM²⁴. This is best explained by the inclusion of small particles of bone produced by bone-sawing operations during hand deboning of the carcass (Protecon MRM) and/or by subsequent bone crushing during retrieval of the MRM (Beehive MRM). Ash contents varied from sample to sample and from species to species and, for red meat MRM at least, appeared to be dependent on the type of machinery used for the processing. Beef MRM produced on Beehive deboners had significantly higher ash contents than samples produced on either Protecon or Hydrau machines although without knowledge of the operating conditions employed it is difficult to assess whether this is a function of the machine itself or the mode of its operation. Poultry meat MRM generally contained similar or only slightly higher amounts of ash than HDM²⁵.

Hydroxyproline (Table V) and nitrogen contents of the MRM samples examined were both lower than would have been expected for hand deboned meats^{25,26,27}. Accordingly, all the MRM samples tested (with one exception) had significantly low apparent fat-free meat contents when calculated using appropriate nitrogen factors (Nf)^{10e,25}. There are three possible reasons for this. Firstly, because of their high tensile strength some connective tissues are withheld during extrusion of the MRM through the machine die. MRM samples are therefore deficient in connective tissues and their collagen contents, as measured by hydroxyproline determination, are significantly lower than comparable HDM²⁵. Since connective tissues are higher in nitrogen content than muscle, the result is a lower overall figure for determined total nitrogen. The exception to this is shown in the results for cooked chicken MRM (sample 33) which is high in both nitrogen (even allowing for its reduced moisture content) and connective tissue (three to five times higher than for the comparable uncooked MRM samples). Here, because the connective tissue has been softened during cooking it has been extruded more easily along with the other MRM material, increasing the total nitrogen and hence the apparent defatted meat content of the sample.

Secondly, a minor contribution to the lower nitrogen figures may be obtained from low-nitrogen materials derived from the bone marrow although no direct evidence of this was sought.

Thirdly, the additional 2–4 per cent. moisture present in the MRM samples would also reduce the fat-free nitrogen (Nf) content, although by too small an amount to account fully for the extremely low “total meat” contents of some of the poultry samples. These results suggest the presence of extraneous water added either in the form of ice as a coolant during the MRM extraction process or more likely as water used for carcass-cooling. Study of Tables II and III shows

that most of the turkey MRM samples (18–29) also contained about 8–10 per cent. of extraneous water.

The presence of additional "natural" moisture, connective tissue abstraction and/or marrow inclusion had a significant effect upon the apparent meat contents of the MRM samples examined. Apparent total meat contents of the beef MRM samples examined were very consistent at an average of 91.3 per cent. with a low spread of results ($s = 1.9$ per cent., $n = 11$) even when samples produced on different types of machine were considered. To give a total apparent meat content of 100 for beef MRM the appropriate Nf factor would have to be 3.09 compared to the figure of 3.55 for HDM^{10e}. Similar results were obtained for pork MRM which had an average apparent total meat content of 90.5 per cent. ($s = 5.7$ per cent., $n = 5$) with an Nf factor of 3.04 compared to 3.45 for hand deboned meat^{10e}, although here fewer samples were examined and those that were showed greater variation. If the effects of added water are ignored, appropriate Nf factors would be for chicken MRM approximately 3.1 and for turkey MRM around 2.6.

The similarity between the fat-free nitrogen contents of beef, pork and chicken MRM (samples 15, 31 and 32) at 3.09, 3.04 and 3.09 respectively implies that it is variations in the connective tissues, either qualitative, quantitative or both, that are responsible for the differences observed between the Nf figures of HDM from different species and that the nitrogen content of the sarcoplasmic proteins are fairly similar. Based upon the results in Table III for single samples of other species, appropriate Nf factors for MRM would be; venison 3.0, veal 3.2, lamb 3.2, and duck 2.8.

PH DETERMINATIONS

pH determinations made upon MRM samples 30–40 are reported in Table V to the nearest 0.05 pH unit. All of the results lie in a narrow band between pH 6.25 (lamb MRM) and pH 6.70 (pork MRM) and are comparable with results reported previously which range from pH 6.0–7.0³. These values are higher than those for corresponding HDM which typically lie between pH 5.4 and pH 6.0, but can rise to pH 6.5 in tissues with low initial glycogen levels⁸.

The reason for this difference in pH between hand deboned and mechanically recovered meat is not entirely clear. It has been suggested that meat in close proximity to the bone, which will be present in higher concentrations in MRM, is of a naturally higher pH because of the lower amounts of lactic acid it produces during glycolysis⁸. Alternatively, the higher pH of MRM has been attributed to the presence of bone marrow which has a pH of 6.8–7.4 and is expressed during the recovery procedure^{3,26}. The increased level of pigmentation suggests that red marrow was present in some of the samples of MRM and that the higher pH may partially be attributed to this. However, if bone marrow content were the only factor in determining the pH then the pork MRM sample (35) would contain over 50 per cent. by weight of bone marrow²⁸; however, microscopical examination showed that this was not so. A third possibility is that the high pressures involved in MRM recovery cause deamination of proteinaceous components thereby releasing ammonia and causing the pH to rise.

BONE AND INORGANIC CONSTITUENTS

Red meat MRM contained more bone than poultry MRM as might be expected from the contrasting treatments undergone by the carcasses prior to MRM recovery and the difference in the hardness of the bones. The product-moment correlation coefficient between ash and bone contents for MRM samples 30–40 was not as high as might be expected ($r = 0.754$, $n = 11$) whereas agreement between ash and phosphorus ($r = 0.969$) and ash and calcium ($r = 0.839$) was considerably better.

This suggests that the method used for the determination of bone content was not satisfactory and that a more reliable figure for bone content might be obtained indirectly from the ash figure. Of the inorganic constituents determined (Tables II and IV) only Ca, Fe and Na were consistently higher and K was consistently lower than the levels found in comparable hand deboned meats. Calcium was 2 to 5 times higher than would be expected in a conventional cut, and was almost certainly derived from small bone particles. It has been suggested that bone content can be estimated in poultry MRM by the equation²³:

$$\text{bone content per cent.} = 6.25 \times (\text{Ca per cent.} - 0.015)$$

A factor to convert P to bone content would also merit further consideration.

Iron contents were on average two to three times higher than in HDM reflecting the increased levels of blood or blood forming (haemopoietic) tissue in the samples. Alteration in the ratio of blood to cellular fluids was also the likely cause of the observed reductions in the ratios of potassium to sodium compared to equivalent HDM²⁴. Magnesium, manganese, zinc, copper and phosphorus contents were similar to levels found in hand deboned meats^{24,25}.

FATTY ACID ISOMERS

Fatty acid isomer profiles of MRM samples 30–40 are shown in Tables VI and VII. Allowing for some natural variation these results are not significantly different from fatty acid profiles of comparable HDM²⁵. This suggests that any marrow lipid present was either similar in composition to tissue lipid or present in insignificant amounts. The single exception is the cooked chicken MRM sample (33) which was significantly lower in polyenoic fatty acids than both hand deboned chicken and the two raw chicken MRM samples (31, 32). This may be attributed to the cooking process undergone by the birds prior to mechanical recovery, which could have three effects; firstly, to introduce non-chicken fat (possibly beef fat used for roasting); secondly, to extract more of the bone marrow lipid; and thirdly, to damage the more unsaturated acids thereby altering the profile.

STEROLS

In the samples examined cholesterol was the only sterol detected; no trace was found of any methyl sterols, dimethyl sterols nor uvaols. Cholesterol contents of MRM samples 30–40 are given in Table V. The reported results are between 30 and 300 per cent. higher than published figures for HDM, which typically range from 50 to 110 mg/100 g for raw samples and up to double that for cooked

TABLE VI
FATTY ACID ISOMER CONTENT OF AVIAN MECHANICALLY RECOVERED MEAT SAMPLES

Fatty acid*	Turkey per cent.	Chicken (frames) per cent.	Chicken (bodies) per cent.	Chicken (cooked) per cent.	Duck per cent.
14:0br iso					
14:0	1.4	1.4	0.8	1.7	0.9
14:1 ω 7					
14:1 ω 5	0.2	0.2	0.2	1.0	0.1
15:0br iso				0.2	
15:0br ante				0.2	
15:0	0.4	0.2	0.1	0.4	0.2
15:1 ω 8					0.1
16:0br iso	1.0		0.3		
16:0	27.2	22.8	23.7	21.0	24.0
16:1 ω 9	0.4	0.6	0.4	0.3	0.4
16:1 ω 7	3.5	4.5	5.1	5.6	3.0
16:1 ω 5				0.3	
16:2 ω 6					
17:0br iso				0.4	
17:0br ante			0.1	0.8	
17:0	0.3	0.3	0.2	0.8	0.2
17:1 ω 8	0.2	0.2	0.2	1.2	0.3
18:0br iso	0.5			0.2	
18:0	9.2	7.1	6.6	9.3	8.4
18:1 ω 9	33.7	36.5	36.9	45.8	40.4
18:1 ω 7	1.9	2.6	2.4	3.7	2.0
18:1 ω 5		0.2	0.1	0.5	
18:1 ω 3			0.1	0.8	
18:2 tt ω ?				1.4	
18:2 ω 6	17.0	18.8	18.4	1.4	15.5
18:2conj. ω 7		0.2	0.1	1.3	0.2
18:3 ω 6			0.1	0.1	
18:3 ω 3	1.2	2.0	1.6	0.6	1.4
18:4 ω 6					
18:4 ω 3			0.1		
20:0	0.2	0.2	0.1	0.2	0.1
20:1 ω 11	0.3	0.3	0.1	0.2	0.2
20:1 ω 9	1.1	0.8	0.6	0.3	0.5
20:2 ω 6		0.2	0.2		0.1
20:3 ω 6		0.3	0.1	0.1	
20:4 ω 6	0.3	0.6	0.4	0.2	1.9
20:5 ω 3			0.4		
22:5 ω 6			0.2		
22:6 ω 3			0.4		

* Fatty acids are named according to standard procedure. The number of carbon atoms in the chain is followed by a colon and then by the number of double bonds in the molecule. The omega (ω) indicates that the carbon atoms are numbered from the methyl terminal group and the numbers following the ω sign indicate the position of the first carbon atom in each double-bonded pair. All double bonds are *cis* configured unless indicated by "t" (for *trans*) and the abbreviation "conj" shows that the double bonds are conjugated rather than the more usual methylene-interrupted. Saturated, branched-chain fatty acids are indicated by the abbreviation "br" followed by "iso" or "ante" (for anteiso) which indicate the position of the branching within the molecule.

samples^{24,29,30}. These differences may be partially explained in terms of the mechanical recovery process during which relatively cholesterol-free connective tissues are abstracted, tending to enrich the remaining MRM tissue³¹. However, enrichment alone cannot account for the higher cholesterol levels of samples 30-40, which are more likely to be caused by the inclusion of some bone marrow constituents and differences in the analytical methodology used.

TABLE VII
FATTY ACID ISOMER CONTENT OF NON-AVIAN MECHANICALLY RECOVERED MEAT SAMPLES

Fatty acid*	Pork per cent.	Lamb per cent.	Lamb (semi-lean) per cent.	Beef per cent.	Veal per cent.	Venison per cent.
14:0br iso		0.1		0.1		0.4
14:0	1.2	5.3	4.7	3.2	4.0	6.1
14:1 ω 7			0.1			
14:1 ω 5		0.2	0.1	0.8	0.6	1.3
15:0br iso		0.2	0.3	0.4	0.2	0.5
15:0br ante		0.3	0.3	0.5	0.2	0.8
15:0	0.3	0.7	0.7	0.8	0.3	1.2
15:1 ω 8						0.2
16:0br iso		0.3		0.3	0.2	0.4
16:0	22.4	21.8	21.4	25.3	21.0	27.3
16:1 ω 9	0.5	0.9	0.4	0.5	0.5	0.5
16:1 ω 7	1.8	1.6	1.5	3.1	3.0	4.8
16:1 ω 5			0.1	0.2	0.2	0.3
16:2 ω 6				0.6		0.2
17:0br iso		0.6	0.5	0.6	0.5	0.5
17:0br ante		0.7	0.7	0.8	0.8	0.6
17:0	0.5	1.2	1.5	1.1	1.1	1.1
17:1 ω 8	0.4	0.7	0.5	0.8	0.9	0.4
18:0br iso		0.2		0.2	0.2	0.1
18:0	16.2	17.8	21.6	16.8	16.9	25.5
18:1 ω 9	36.9	30.8	27.8	33.2	40.6	16.7
18:1 ω 7	3.4	6.7	7.3	3.9	3.2	4.6
18:1 ω 5		0.9	1.5	0.9	0.5	0.6
18:1 ω 3	0.3	0.4	0.6		0.3	
18:2 tt		2.0	2.5	1.7	1.0	0.7
18:2 ω 6	10.2	1.7	1.5	2.0	1.9	1.7
18:2 conj. ω 7	0.2	2.3	2.0	0.7	0.7	0.8
18:3 ω 6			0.2	0.2		0.4
18:3 ω 3	0.7	1.3	1.5	1.0	0.5	0.8
18:4 ω 6	0.3					
18:4 ω 3		0.1	0.1			
20:0	0.4	0.2	0.1	0.1	0.1	0.5
20:1 ω 11					0.1	
20:1 ω 9	1.8	0.6	0.5	0.2	0.3	0.5
20:2 ω 6	0.7					
20:3 ω 6	0.2					
20:4 ω 6	1.2	0.4			0.2	0.5
20:5 ω 3	0.4					
22:5 ω 6						
22:6 ω 3						

* See footnote to Table VI.

MICROSCOPY

Studies on the histochemical characterisation of MRM are continuing and incomplete²¹. However, there are several microscopical features of MRM that readily set it apart from equivalent, comminuted, HDM.

Staining the samples with toluidine blue and sirius red F3BA showed the muscle tissue to be extensively damaged while retaining sufficient of its microstructure to be identified as being of animal origin. The major difference from comminuted HDM was that the sarcolemma was often indistinct or absent and many of the muscle cell nuclei were no longer visible. In addition, few of the muscle fibres remained attached together, and many were irregular in shape and had lost all semblance of the familiar cross-striations. A certain amount of amorphous material was also visible. Take-up of the blue basic dyestuff by MRM appeared to be similar to that of HDM.

Sections of red meat MRM stained with alizarin red S contained variable numbers of very small bone particles, many less than 1 mm in diameter, which would appear to be diagnostic^{7,21}. Such particles were not seen to the same extent in poultry MRM, leading to the conclusion that they were probably derived from the "bone-dust" adhering to bone and meat surfaces following sawing up of the red meat carcass.

To date, staining of samples with Carazzi's haematoxylin has failed to demonstrate identifiable signs of haemopoietic tissue in MRM although work on red marrow samples has shown that this is the technique most likely to do so²¹.

Discussion

Mechanically recovered meat (MRM) is the term used in the UK to describe what the United States Department of Agriculture (USDA) defines as "the finely comminuted product resulting from the mechanical separation and removal of most of the bone from attached skeletal muscle of livestock carcasses and parts of carcasses"³². The fact that the UK term has received general acceptance is in contrast to the position in the USA where the USDA has been pressured by both manufacturing and consumer interest groups into making several changes of name. In 1976 the term "Mechanically Deboned Meat, MDM"³³ was adopted only to be changed in 1977 to "Tissue From Ground Bone, TFGB"³⁴, following a court ruling that MDM was not meat as traditionally defined because of its bone particle content which must be regarded as an addition made during processing. In 1978 TFGB was rejected as misleading, because it implied that the product was made wholly from parts of bone, and was replaced by "Mechanically Processed (Species) Product, MS(S)P"³⁵.

However, although the UK is fortunate in having a single and undisputed name for the product this does not make MRM any less variable in its composition. Even from the data presented here, the term MRM obviously does not describe a single chemically-definable product. Its composition is subject to variation not only from the differences occurring naturally between and within animal species but also from differences in machine type and operating practice. Some types of MRM, for example chicken and turkey, are more consistent in composition than others such as beef, where different samples might derive

from different parts of the carcass or even different breeds of cattle. From Tables I and III it can be seen that lamb MRM pressed from ribs and neck bones (sample 36) is very different in composition to lamb MRM produced under the same conditions from belly end of ribs (37). Add to this the fact that the fat content of poultry MRM can be raised by increasing the amount of skin processed with the carcass and it becomes obvious that, within certain limitations, MRM can be tailored to suit any particular market or end product.

Primary factors affecting MRM composition appear to be the animal species, the part of the animal used and its condition (for example whether or not it is trimmed of fat, cooked or frozen) as well as the type of machine used and the conditions under which it is operated (Table VIII). Because of its variable composition MRM presents several problems for the analyst wishing to detect or quantify its inclusion in a meat product.

(i) A single, simple chemical index of the presence of MRM will be difficult to find. The likelihood of finding an accurate and reliable quantitative index would appear to be even more remote.

(ii) MRM does have certain characteristics that may aid in its qualitative detection but often several of these would need to be considered together. MRM is more deeply coloured, can be expected to have a higher pH, can contain more bone, can have higher levels of cholesterol, Ca, and Fe, and can have a lower K/Na ratio and lower contents of connective tissue material and nitrogen than corresponding hand deboned meats.

(iii) Of the chemical parameters available for MRM detection total haeme pigment (as indicated by iron content) or the ratio of haemoglobin/myoglobin would probably be the best.

(iv) The microstructure of MRM is distinctive and quite different from comminuted HDM. Small particles of "bone dust" can be seen in red meat but not in all samples of poultry MRM while signs of haemopoietic marrow should be detectable in some types of MRM. However, when incorporated in comminuted meat products together with traditional ingredients, MRM would be much more difficult to identify. Also, the absence of bone particles would not prove the absence of poultry MRM.

(v) Current regulations controlling the meat content of foods make no reference to MRM³⁶. The meat product manufacturer might therefore assume, unless advised otherwise by his supplier, that MRM can be used to replace hand deboned meat in product formulations on an equivalent weight basis. However, because of the lower fat-free nitrogen contents of MRM, this could result in a product containing less than the legal requirement for meat content as calculated following chemical analysis^{10f}.

Acknowledgements

The authors thank Dr. F. Olga Flint of the Procter Department at the University of Leeds for her work and advice on the microscopy of MRM and the staff of the Food and Nutrition Division of LGC for compositional analyses. Funding for this study was provided by LGC Requirements Committee and the Ministry of Agriculture, Fisheries and Food.

TABLE VIII

MAJOR SPECIES OF MECHANICALLY RECOVERED MEAT: PROXIMATE ANALYSES
ARRANGED ACCORDING TO MACHINE USED FOR MEAT REMOVAL

Species/ machine		Moisture per cent.	Ash per cent.	Nitrogen per cent.	Nx6.25 per cent.	Fat per cent.	Total analysis per cent.	Total meat* per cent.
Beef								
Protecon	i	51.5	1.12	2.15	13.4	32.2	98.2	92.8
	ii	56.2	1.11	2.13	13.3	32.5	103.1	92.5
	iii	59.6	1.25	2.25	14.0	23.4	98.3	86.8
	iv	51.5	0.95	2.13	13.3	33.0	98.8	93.0
	v	60.7	1.14	2.54	15.9	21.1	98.8	92.6
	vi	59.9	1.30	2.37	14.8	23.6	99.6	90.4
Beehive	vii	46.7	2.78	1.82	11.4	37.8	98.7	89.1
	viii	39.6	2.55	1.52	9.5	48.8	100.4	91.6
	ix	44.5	2.76	1.86	11.6	38.6	97.5	91.0
	x	46.4	2.55	1.86	11.6	40.5	101.1	92.9
Hydrau	xi	54.0	0.89	1.92	12.0	37.6	104.5	91.7
Mean (<i>n</i> = 11)		51.9	1.67	2.05	12.8	33.6	99.9	91.3
Pork								
Protecon	i	63.1	1.14	2.61	16.3	19.1	99.6	94.8
	ii	56.0	0.90	2.22	13.9	29.9	99.8	94.2
	iii	67.2	1.08	2.48	15.5	13.4	97.2	85.3
	iv	69.3	1.32	2.38	14.9	14.3	99.8	83.3
Hydrau	v	61.1	0.96	2.50	15.6	22.3	100.0	94.8
Mean (<i>n</i> = 5)		63.3	1.08	2.44	15.2	19.8	99.3	90.5
Chicken								
Protecon	i	60.4	0.74	2.27	14.2	23.4	98.7	86.5
	ii	79.8	0.66	2.04	12.8	7.1	100.4	63.8
	iii	76.0	0.74	2.21	13.8	11.3	101.8	72.7
	iv	65.1	0.84	2.56	16.0	17.8	99.7	88.9
	v	57.1	0.74	2.24	14.0	27.9	99.7	90.1
Mean (<i>n</i> = 5)		67.7	0.74	2.26	14.2	17.5	100.1	80.3
Turkey								
Protecon	i	81.7	0.53	1.98	12.4	4.5	99.1	61.0
	ii	79.0	0.43	2.52	15.7	5.2	100.3	77.2
	iii	79.2	0.64	2.03	12.7	6.7	99.2	62.3
	iv	76.6	0.70	2.24	14.0	8.4	99.7	69.7
	v	78.7	0.70	2.26	14.1	6.0	99.5	67.8
	vi	78.3	0.58	2.14	13.4	5.4	97.7	64.1
	vii	77.6	0.70	2.51	15.7	5.4	99.4	74.1
	viii	79.1	0.74	2.18	13.6	6.6	100.0	66.4
	ix	77.7	0.71	2.29	14.3	4.1	96.8	66.8
	x	79.8	0.63	2.21	13.8	6.2	100.4	66.7
	xi	72.6	0.66	2.34	14.6	5.6	93.5	69.6
	xii	79.3	0.61	2.19	13.7	6.8	100.4	66.8
	xiii	70.3	0.67	2.23	13.9	13.1	98.0	74.2
Mean (<i>n</i> = 13)		77.7	0.64	2.24	14.0	6.5	98.8	67.6

* See footnote to Table II.

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