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SOME EFFECTS OF ADDED WATER AND SALT ON THE COOKING LOSSES OF MEAT

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SUMMARY

Mixtures of meat, water and salt were heated under controlled conditions and the cooking losses measured. Large variations occurred between individual samples of meat but it is shown that the lowest cooking losses were produced at salt concentrations between 0.5M and 1.5M in the total water in the mixture, i.e. under the conditions favouring maximum solubilisation of the meat protein. Pre-salting the meat reduced the cooking losses of mixtures with these optimal salt concentrations. This is consistent with the current view that solubilising of proteins assists the retention of juices on cooking. However, if drainage during cooking was prevented, increases in loss were found at these salt concentrations. This requires some modification of the hypothesis that coagulation of the solubilised protein *in situ* is also necessary.

Quelques effets des additions d'eau et sel sur les pertes lors de la cuisson de la viande.

RESUME

Des melanges de viande, d'eau et de sel étaient cuites dans des conditions controllables et les pertes lors de la cuisson furent mesurées. Il y avait de grandes variations entre les échantillons individuels mais l'on a montré que les pertes les plus reduites étaient produites aux concentrations de sel entre 0.5M et 1.5M, calcul basé sur l'eau totale du melange, c'est à dire sous les conditions les plus favourable pour la solubilisation maximale des proteines de la viande. Le prè-salage de la viande reduisait les pertes à la cuisson de ces melanges à ces concentrations en sel optimales. Ceci est en accord avec l'idée courante que la solubilisation des proteines favourise la rétention de jus pendant la cuisson. Cependant si l'on empêchait les jus de s'échapper pendant la cuisson, les pertes augmentaient dans la gamme de concentrations en sel considerée. Ceci oblige à modifier l'hypothèse que la coagulation <u>in situ</u> des proteines solubilisées est aussi necessaire.

Einige Einwirkungen des Zusatzes von Wasser und Salz auf die Kochverluste von Fleisch

ZUSAMMENFASSUNG

Mischungen aus Fleisch, Wasser und Salz wurden unter kontrollierten Bedingungen erhitzt und die Kochverluste gemessen. Obwohl erhebliche Unterschiede zwischen einzelnen Fleischproben festgestellt wurden, konnte dennoch nachgewiesen werden, daß die niedrigsten Kochverluste bei Salzkonzentrationen zwischen 0,5 und 1,5 Mol, bezogen auf den gesamten Wassergehalt der Mischung, entstanden, also unter den günstigsten Bedingungen für die Solubilisation des Fleischproteins. Ein vorhergehendes Salzen des Fleischs verringerte die Kochverluste der Mischungen bei den genannten, optimalen Salzkonzentrationen. Dieses Ergebnis deckt sich mit der gegenwärtigen Auffassung, daß die Solubilisation des Proteins die Retention der Fleischsäfte während des Kochprozesses begünstigt. Dennoch, wurde eine Entsaftung während des Kochens unterbunden, so wurden bei diesen Salzkonzentrationen erhöhte Verluste festgestellt. Unter diesen Umständen erscheint es angebracht, die Hypothese der Notwendigkeit einer zusätzlichen Koagulierung des solubilisierten Proteins *in situ* entsprechend abzuwandeln.

INTRODUCTION

Much effort has been devoted to the measurement and explanation of water binding capacity in fresh meat (e.g. Hamm, 1960) and to the extension of this concept to cooked meat products (e.g. Hamm, 1973). However, it is clear that there is only a poor statistical correlation between measurements of water binding capacity made on fresh meat and on the same meat after cooking (Herring, Hagyard and Hansen, 1971). Measurements of cooking losses can be made on real or simulated meat products (e.g. Karmas & Thompson, 1964; Wismer-Pedersen, 1966; Bartels et al., 1970; Hamm & Schneider, 1972) but while such experiments give useful empirical information about the meat products in question, the complexity of the recipes makes it difficult to interpret the results in terms of the fundamental chemical changes taking place.

It was decided in this laboratory to make a direct study of factors affecting the cooking losses of meat products by cooking controlled mixtures under standard conditions and observing the losses which occurred. By working on the small scale, many combinations of composition and the usual manufacturing processes such as mincing, chopping, etc. could be tested in a short time and it was hoped that by planning the experiments appropriately, the separate effects of each variable could be quantified.

This paper describes some of the results.

APPARATUS, MATERIALS AND METHODS

Various other workers have used simple model cooking systems to measure the losses of meat on heating. (Wierbicki, Kunkle & Deatherage, 1956; Sherman, 1961; Hellendoorn, 1962; Miller, Saffle & Zirkle, 1968) but all have used different conditions and no one system can be regarded as a standard. For this work it was decided to cook the samples in tubes immersed in a constant temperature water bath and to measure the juices which drained out without centrifuging. Fig. 1 A shows the apparatus used for the majority of the experiments reported here. The meat sample to be cooked was supported above the bottom of a polypropylene test tube, 11 cm x 4 cm, so that the cooked out liquid drained away from the meat during cooking. Fig. 1 B shows an alternative version in which the meat remained immersed in its own juice during cooking but could be raised above the liquid afterwards. A constant weight of sample was taken, 40 ± 0.1 g, and heated in a water bath at 80° for 28 mins. After cooking, the weight of the separated liquid was determined and the percentage cooking loss calculated. The red colour of the raw meat just disappeared under these conditions, i.e. the meat was "just cooked". It has also been shown by other workers that the major part of the potential cooking losses occurs under conditions such as these. (Wierbicki, Kunkle & Deatherage, 1956; Hamm, 1966).

Meat

Meat of average manufacturing quality was used:

Pork This was shoulder meat, fat content 2 - 3%, occasionally 5%, delivered 1 day after slaughter, occasionally 2 days, and normally used on the day of delivery.

Beef Shin meat was used, fat content 3 - 8%, delivered 2 days after slaughter and normally used on the day of delivery.

Any obvious fat or connective tissue was trimmed off the meat before use.

Preparation of mixtures

One day's experiments were taken as a unit and all the meat for the day was minced through a 5 mm plate and thoroughly mixed.

To make mixtures of lean meat with water salt or both, the necessary quantities of salt and distilled water were mixed together to dissolve the salt or to form a saturated brine containing excess salt. The solution or mixture was then added to 100 g of minced meat in a beaker and the whole gently mixed with a kitchen fork. Homogeneous mixtures could be made when the proportion of added water was below about 40 g per 100 g of meat in the absence of salt, or up to 75 - 100 g as the proportion of added salt was increased. At higher water levels it was difficult to incorporate the water evenly but with care a satisfactory degree of agreement between duplicate cooking tests (difference between % cooking losses = 1% or less) could be obtained despite this difficulty.

Expression of results

All the results quoted are the mean values of duplicate determinations, agreeing within the limits just stated. In describing the composition of meat mixtures and in expressing the results of the cooking tests the convention was followed of expressing all proportions as percentages of the lean meat present, e.g. x g salt per 100 g meat = x% salt.

Comparison among the factors can thus be readily made since the proportion of meat is common to all expressions, but it should be noted that this is a different calculation from that usually made, in which percentages are referred to 100 parts of the complete mixture.

For some purposes the salt concentration in the total water in the mixture was calculated, making the assumption that the 100 parts of meat present contributed 75 parts of water.

RESULTS

Effects of added water and salt

The results of a series of experiments with pork meat are set out in Table I. Each line in the table gives the results of tests on a single large uniformly mixed sample of meat.

As the first column shows, the cooking losses of different meat samples, without any addition of water or salt, varied from 18 to 27%, mean 23.5%.

When samples containing added water but no salt were cooked, (Table I, second column) the cooking losses were never as great as the sum of the added water plus the cooking loss of the meat with no water. That is to say, the addition of water to the minced meat resulted in the retention of some of the water that one might have expected to be lost.

The Table shows that increasing the proportion of added salt in meat samples containing constant levels of added water produced first a reduction in cooking loss, then an increase. Differences occurred between meat samples receiving the same treatment, both in the extent of the change in cooking loss and in the salt concentrations at which the minimum loss occurred. Despite these variations from sample to sample a strong pattern is discernible in the Table, with minimum cooking losses occurring when the ratio of added salt: added water was about 8 : 100 or 1 : 12.

Fig. 2 presents the same experimental data as Table I but shows the changes in yield of cooked meat, calculated from the equation:

Yield = uncocked meat + added water + added salt - cooking loss

= 100 + added water % + added salt %-cooking loss %

At each level of added water the yield reached a maximum which remained approximately constant over a wide range of salt contents. This region of approximately constant yield is shown in Fig. 3 by the bold lines. Again, marked differences between different meat samples given the same treatment can be observed, but the maximum yield occurred when the ratio of added salt to added water was about 8 : 100. If the water in the uncooked lean meat is taken into account, the relationship becomes more precise. Table II gives the salt concentrations in the total water associated with the regions of maximum, approximately constant, yield, and shows that these occurred when the salt concentrations in the total water in the mixture lay between 3 and 8%, or approximately 0.5M to 1.4M.

Effect of pre-salting

Table III gives the results of an experiment in which mixtures of pork meat, salt and water were made and then each divided into two parts. One part was cooked as soon as practicable, the other was held at 5^{o} for 24 hours before cooking.

In the samples cooked with little delay, the same effects of added salt and water can be observed as previously; the minimum losses occurred at salt concentrations which can be calculated to be 8 - 36% in the added water, equivalent to 4 - 9% or 0.7M - 1.5M in the total water. The cooking losses of meat pre-salted and held 24 hours were lower than the values obtained before holding, and from the Table it can be shown that the maximum reduction in loss occurred at salt concentrations of 7 - 32% in the added water or 4 - 8%, 0.7M - 1.4M, in the total water.

Effect of preventing drainage during cooking

This experiment was carried out using minced beef. Part of each sample was cooked in the apparatus shown in Fig. 1 A, in which the cooking liquor was allowed to drain away during cooking. A second part was cooked in the apparatus shown in Fig. 1 B, in which drainage was prevented and the meat was cooked in its own liquor. The results are set out in Table IV.

The samples cooked with drainage showed the same pattern of response to added salt and water as the previous samples of pork meat, cooked in the same way. The salt concentrations at which minimum cooking losses occurred can be calculated from the data in the Table as 8 - 16% in the added water, 3 - 6% or 0.5M - 1.0M in the total water.

The effect of preventing drainage during cooking depended greatly on the salt concentration of the mixture. In some cases a reduction in cooking loss occurred: the maximum reduction in loss was at salt concentrations which can be calculated as 0 - 3% in the added water, 0 - 2% or 0 - 0.3M in the total water. On the other hand the losses were increased under a range of conditions corresponding to 2 - 10% salt in the total water, 0.3M - 1.7M.

DISCUSSION

The wide variation between different samples of meat, compared with good agreement between duplicate samples of the same meat, has already been referred to. In meat samples without any added salt or water the range of cooking losses was from 18% to 27% among 11 samples of pork shoulder meat and from 6% to 29% among 5 samples of shin beef. Samples also varied in their response to the treatments applied, both in the magnitude of their response at its maximum and in the concentrations of added salt and water at which the maximum response occurred. Despite this variablilty, underlying general patterns of behaviour can be clearly seen. When water alone was added to the meat there was a small increase in the net yield after cooking, roughly proportional to the amount of added water. A similar effect was demonstrated in freshly slaughtered uncooked meat by Hamm (1960), using the press method to measure the water binding capacity, but in meat tested 2 or more days after slaughter, as in our experiments, he found that the effect was reversed or disappeared. He attributed the increase in water binding capacity in the freshly slaughtered meat to an increase in inter-molecular space as a result of electrical repulsion between protein molecules, associated with a change in pH. However, it is not clear from this kind of explanation why the effect should disappear from uncooked meat with time and reappear again on cooking.

Large changes in cooking loss were produced by additions of salt and water together. Clearly, many of the salt concentrations used in these experiments would give products which would be inedible, but this problem may be temporarily set aside while we consider the implications of the effects on cooking loss. Wirth (1972) has given some examples of its practical consequences.

Minimum losses, or maximum yields, were produced at salt concentrations corresponding approximately to 0.5M to 1.5M in the total water in the mixture, including the water present in the lean meat. This is the salt concentration at which all the meat proteins are known to become soluble (Haurowitz, 1963). It can also be observed in Fig. 2 that the yield was higher with higher proportions of added water, that is, with increasing ratio of 'solvent' - 0.5M to 1.5M salt solution - to meat protein. Table III shows also that the losses were lower when the same 'solvent' was in contact with the meat for a longer time before cooking. Other workers (Kotter, 1960; Sherman, 1961; Hamm, 1973) have advanced the hypothesis that the retention of juices by meat on cooking is favoured by the solubilisation of the protein before cooking, and the results of these experiments are in complete agreement with this view.

However, Sherman (1961) also showed that if meat was mixed with salt and water, allowed to stand for 16 hours and then the separated fluid was removed from the mixture before cooking, the cooking loss was higher than if the fluid had been allowed to remain with the meat during cooking. He concluded that solubilised protein, remaining in contact with the meat during cooking, was responsible for the better water retention in the latter case. Later workers have adopted this view and supposed that coagulation of the solubilised protein during heating plays an important role in retaining moisture in the cooked meat (Kotter, 1960; Hamm, 1973). The result of our experiment in which drainage of the meat during cooking was either permitted or prevented (Table IV) is however difficult to reconcile with this hypothesis. Allowing drainage during cooking may be considered to be a variation of Sherman's experiment in which drainage was carried out before cooking, and one might therefore predict from his results that the cooking loss when drainage was permitted would be higher than when it was prevented. In fact, at the salt concentrations which favour protein solubilisation, the opposite occurred. Reduction in loss due to preventing drainage (or increase in loss due to permitting it) only occurred in the absence of salt or at low salt concentratinns.

This suggests that the concept of moisture retention by coagulation of solubilised protein is an over-simplification and that it is necessary to consider more closely the behaviour of the different fractions of the protein. The sarcoplasmic proteins, for example, which are soluble without the addition of salt and which coagulate at relatively low temperatures (Charpentier, 1959; Scopes, 1964) are likely to be of great importance.

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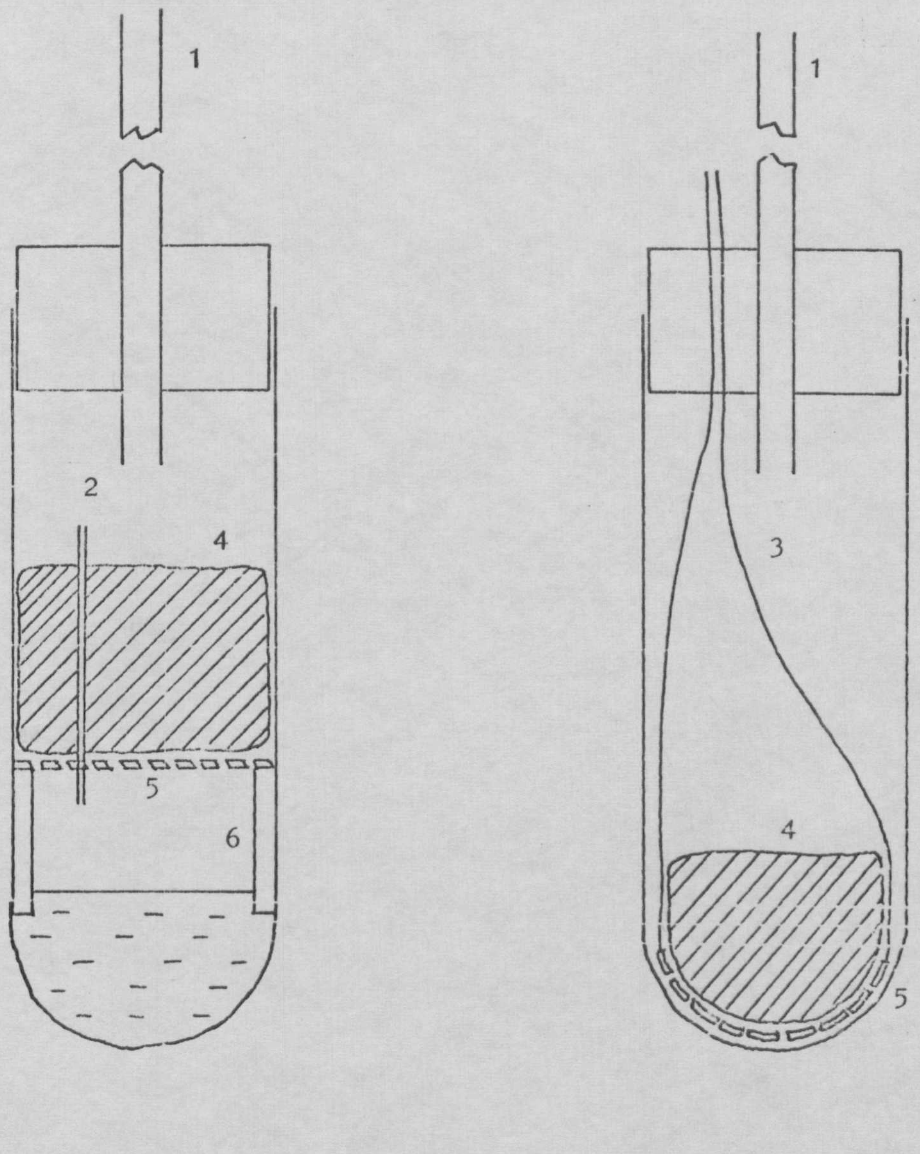
FIGURE 1

Cooking Apparatus

A. Allowing drainage during cooking

B. Preventing drainage during cooking



1. Air Condenser
2. Vapour escape tube
3. Threads attached to perforated plate
4. Sample
5. Perforated plate
6. Supporting tube

FIGURE 2

COOKED YIELD of
MEAT-SALT-WATER MIXTURES

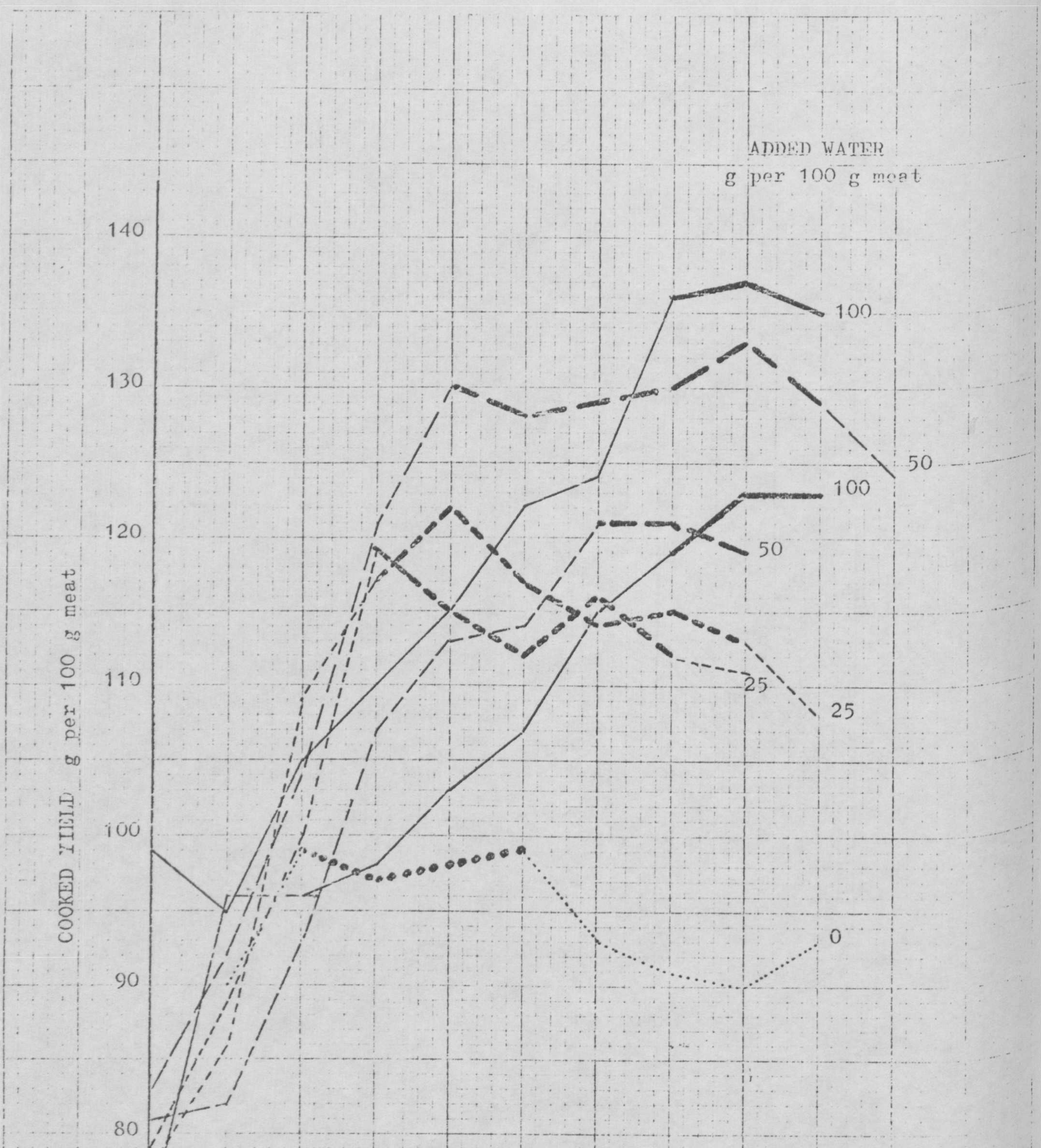


TABLE I

Effect of added water and salt on percentage cooking loss of lean minced pork (a,b,c,d)

Added water %	Control (e)	Added Salt % 0	1	2	3	4	5	6	7	8	9	10
0	18		11	3	6	6	6	13	16	17	16	
25	24	46	37	27	9	14	18	15	20	22		
	25	47	40	18	9	7	13	17	17	20	27	
50	25	69	69	59	45	41	41	35	36	39		
	23	63	59	48	32	24	27	27	27	25	30	34
100	23	101	106	97	93	89	83	82	71	71	74	
	27	125	105	108	105	101	93	91	88	85	86	

Notes (a) All percentages as g per 100 g meat

(b) Cooked with drainage

(c) Results on the same horizontal line refer to the same sample of meat

(d) Lowest loss on each line underlined

(e) No added water or salt

TABLE II

Salt concentrations as per cent of total water (a), associated with maximum cooked yield of lean minced pork (b), calculated from data of Table I.

	Added Salt % (c)										
Added water % (c)	0	1	2	3	4	5	6	7	8	9	10
0			2.7	4.0	5.3	6.7					
25				3.0	4.0	5.0	6.0	7.0			
				3.0	4.0	5.0	6.0	7.0	8.0		
50							4.8	5.6	6.4		
					3.2	4.0	4.8	5.6	6.4	7.2	
100								4.0	4.6	5.1	
								4.0	4.6	5.1	

Notes (a) Salt concentration = added salt % ÷ (added water % + 75% water in meat) x 100

(b) Samples with maximum yield taken as those shown by bold lines in Fig. 3

(c) g per 100 g meat

TABLE III

Effect of pre-salting on percentage cooking loss of lean minced pork (a, b, c, d)

	Added water %	Control (e)	Added salt % 0	1	2	3	4	5	6	7	8
ca. 30 min delay	0	18		11	3	6	6	6	13	16	17
	25	24	46	37	27	9	14	18	15	20	22
	50	25	69	69	59	45	41	41	35	36	39
	100	22	102	101	96	92	91	92	87	86	83
	100	20	105	106	98	98	90	89	89	89	86
24 hr delay (pre-salting)	0	22		12	6	3	8	6	7	13	15
	25	24	44	34	18	7	7	8	8	9	5
	50	25	66	61	59	35	22	22	20	20	17
	100	12	97	98	82	85	81	87	71	65	64
	100	20	99	103	98	99	90	86	73	79	55
Reduction in cooking loss due to pre-salting (f)	0	-4		-1	-3	3	-2	0	6	3	2
	25	0	2	3	9	2	7	10	7	11	17
	50	0	3	8	0	10	19	19	15	16	12
	100	10	5	3	14	7	10	5	16	21	19
	100	0	6	3	0	1	0	3	11	10	31

Notes (a) All per centages as g per 100 g meat

(b) Cooked with drainage

(c) Results on same horizontal line refer tothe same samples of meat: corresponding lines in the "ca. 30 min delay" and "24 hr delay" sections also refer to the same samples of meat

(d) Lowest cooking loss or greatest reduction in loss on each line underlined

(e) No added water or salt

(f) Reduction in loss shown positive, increase in loss shown negative

TABLE IV

Effects of cooking with and without drainage on percentage cooking loss of lean minced beef (a,b,c)

	Added water %	Control (d)	Added Salt %				
			0	2	4	6	8
With drainage	0	24	-	9	<u>8</u>	10	10
	25	17	40	9	<u>8</u>	8	9
	50	6	58	53	37	29	<u>26</u>
	75	21	82	78	57	39	<u>31</u>
	100	29	114	117	109	105	<u>102</u>
	150	19	149	146	144	<u>123</u>	125
Drainage prevented	0	19	-	9	<u>8</u>	11	15
	25	13	30	16	<u>11</u>	13	18
	50	14	53	51	38	36	<u>34</u>
	75	17	70	72	63	59	<u>50</u>
	100	21	107	95	100	96	<u>89</u>
	150	13	120	117	108	<u>106</u>	115
Reduction in loss due to preventing drainage (e)	0	5		0	0	-1	-5
	25	4	<u>10</u>	-7	-3	-5	-9
	50	-8	<u>5</u>	2	-1	-13	-8
	75	4	<u>12</u>	6	-6	-20	-19
	100	7	7	<u>22</u>	9	9	13
	150	6	29	29	<u>32</u>	17	10

Notes
(a) All percentages as g per 100 g meat
(b) Results on the same horizontal line refer to the same sample of meat: corresponding lines in the "with drainage" and "drainage prevented" section also refer to the same samples of meat
(c) Lowest cooking loss or greatest reduction in loss on each line underlined
(d) No added water or salt
(e) Reduction in loss shown positive, increase in loss shown negative