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Causes of cooking loss on heating of meat

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Water is the major component of muscle. Lean red meat contains up to 75 % water. The loss of water in this food is an important economic and palatibility factor. There are two main kinds of exudation: a) the drip loss of raw meat and b) the cooking loss of meat on heating. Together with the hardening of the tissue and its discoloration, the loss of juice is one of the most remarkable effects of heating on meat; the latter will be the subject of this presentation. The possible factors which affect cooking loss are numerous. Our studies were confirmed to:

1st. The relationship between the final temperatures of heating and the amount and chemical composition of the liquid released;

2nd. Identifying the chemical and physical reasons for the cooking loss;

3rd. Due to the wide spread deviations of meat quality we compared normal meat quality with meat of PSE characteristics from pork and DFD attributes from beef.

Materials and methods

Experiments were performed with beef muscles of normal quality ($pH_u < 6.0$) and DFD attributes ($pH_u > 6.2$) and pork muscles with normal quality ($pH_1 > 6.0$, $pH_u < 5.8$) and PSE attributes ($pH_1 < 5.8$). Small pieces of muscles (2 x 200 x 400 mm) were cut, weighed and sealed in polyethylene bags. 4 - 6 pieces were assigned to each of six endpoint temperatures (45,55,65,75,85 and 95°C). The samples were heated in a waterbath with an initial temperature of 20°C and at a heating rate of 2.5°C/min. After cooking (reaching the final temperature) they were cooled in cold tap water, drained, mopped gently dry with paper tissue and reweighed. The difference between the raw and the cooked weights was recorded as cooking loss and expressed as percentage of the raw weight. The juice of each group was collected and centrifuged; the supernatant was analyzed for total nitrogen (N x 6.25) and acid-precipitable proteins (Kjeldahl-Method).

Differential scanning calorimetry (DSC) offers a direct method to study the thermal transition of muscle proteins "in situ". Raw meat samples of about 40 mg were sealed in alumina pans. In the first run the samples were heated up to the chosen final temperature with a velocity of 2.5°C/min and than immediately cooled down to 20°C. In the second run the samples were reheated from 20 to 100°C at 10°C/min. The remaining denaturation enthalpies obtained during the second heating were estimated.

The sarcomere length of raw and cooked muscles was measured with the laser diffraction method according to VOYLE (1971).

Results and discussion

Between the initial temperature of 20°C and 45°C no or very little release of exudate was observed (fig. 1). From 50 up to 95°C the cooking loss increased with increasing endpoint temperature of heating, reaching 35 - 45% of the raw weight at 95°C. This tendency applied to all meat qualities. Muscle samples with DFD attributes, however, showed markable higher cooking yields (less cooking loss) compared to the other meat qualities. This divergence is attributed to the high ultimate pH value of the DFD beef, which is accociated with a higher water binding capacity. On heating beef to 100°C, KIM et al. (1985) found a rise of cooking loss with decreasing pH values of meat.

Using PSE-pork we observed repeatedly that within the temperature intervall 65 to 85°C (the range of home-cooking of meat) the weight losses were significantly higher with PSE-pork than with meat of normal quality.

Heating causes protein denaturation which is followed by the coagulation of myofibrillar proteins and the shrinkage of the myofilaments and tightening of the microstructure of myofibrils; these factors increase the amount of "free water" in muscle tissue. HOSTETLER and LANDMANN (1968) found that as the myofibrillar proteins coagulate after denaturation by heat, they loose their water holding capacity, resulting in higher cooking losses.
As free water escapes from the myofibrillar spaces, it carries with it some soluble sarcoplasmic proteins.

Table 1 shows amounts of total N x 6.25 and acid-precipitable proteins in the cooking juice of the different meat qualities. Both were related to the amount of cooking loss. Up to the final temperature of 75°C the total nitrogen and protein content decreased, above 75°C no further reduction occured. The decrease of nitrogen components in cooking juice may be a result of heat-induced protein denaturation and therefore a decreased solubility of these proteins has to be expected (DAVIS and ANDERSON, 1983). DFD beef showed higher total N and acid-precipitable protein content which is believed to be due to a higher protein solubility resulting from its high ultimate pH value. PSE condition is caused by low pH and high temperatures in the early stage post-mortem and sarcoplasmic proteins of PSE meat have been shown to be partially denatured. This could be the cause for the diminished protein content in juice of PSE-pork compared with normal pork heated at temperatures below 75°C.

The considerable decrease of water-holding capacity during heating of meat, which results in the release of juice, is due to a tightening of the myofibrillar network by heat-denaturation of the proteins (HAMM, 1977). DSC offers a direct method for studying how the different main proteins in meat denature with increasing temperature. For meat samples, which has been heat-treated prior to the DSC analysis, the area under its peak is an expression of the remaining denaturation enthalpy which is proportional to the amount of remaining undenaturated protein in the sample after the first heat treatment.

Tab.1: Total N x 6.25 and the part of acid-precipitable proteins in the cooking juice of meat of different qualities which was heated with 2.5°C/min to final temperatures between 45° and 95°C

final temperature of heating °C	p o r k				b e e f			
	Normal (n = 4)		PSE (n = 5)		Normal (n = 3)		DFD (n = 3)	
	RP[a] g/100 g	SP[b] % of RP	RP[a] g/100 g	SP[b] % of RP	RP[a] g/100 g	SP[b] % of RP	RP[a] g/100 g	SP[b] % of RP
raw meat	12,81[c,d]	-	11,1[c,d]	79,1[c,d]	10,44[c,d]	-	-	-
45	11,63[d]	-	8,7[d]	72,6[d]	-	-	-	-
55	10,23 ± 1,1	77,31 ± 3,67	8,6 ± 0,93	71,0 ± 6,83	9,03 ± 0,18	67,32 ± 4,85	15,19 ± 0,54	85,15 ± 0,24
65	6,49 ± 1,0	58,05 ± 12,7	5,7 ± 0,35	45,7 ±11,27	6,09 ± 0,20	47,59 ± 5,76	10,07 ± 0,63	75,25 ± 4,07
75	4,18 ± 0,2	18,88 ± 5,00	4,2 ± 0,21	21,2 ± 5,32	4,49 ± 0,17	28,24 ± 4,12	5,94 ± 0,73	42,95 ± 10,2
85	4,04 ± 0,2	24,44 ± 6,49	4,2 ± 0,24	27,4 ± 9,14	4,36 ± 0,32	38,70 ± 4,81	5,24 ± 0,28	42,21 ± 10,2
95	4,11 ± 0,2	26,53 ± 4,86	4,2 ± 0,18	25,7 ± 8,22	4,14 ± 0,41	21,78 ±10,22	5,07 ± 0,10	44,22 ± 16,5

a) RP = total N x 6.25 [g/100 g] ; b) SP = acid-precipitable protein % of RP ;
c) measured in drip loss; d) only 1 sample available;

Fig. 2 shows that the amount of remaining denaturation enthalpy of pork was linearly related with cooking loss up to about 15 % equivalent to temperatures of heating of about 75°C. Above this temperature and cooking loss no relationship between denaturation and cooking loss could be established. This result of denaturation of 90 % of muscle proteins at temperatures of about 75°C is confirmed by the results of table 1. Total Nx6.25 and acid soluble protein are reduced in the supernatant up to 75°C. Above this temperature no changes in N x 6.25 and only very minor changes in acid-soluble proteins in the supernatant are observed. Reaching only about 40 % of the total cooking loss, 90 % of muscle proteins are denatured. In PSE meat the same characteristics could be observed. From these results it can be concluded that the transformation of native protein structures cannot be the sole cause of the release of cooking juice.

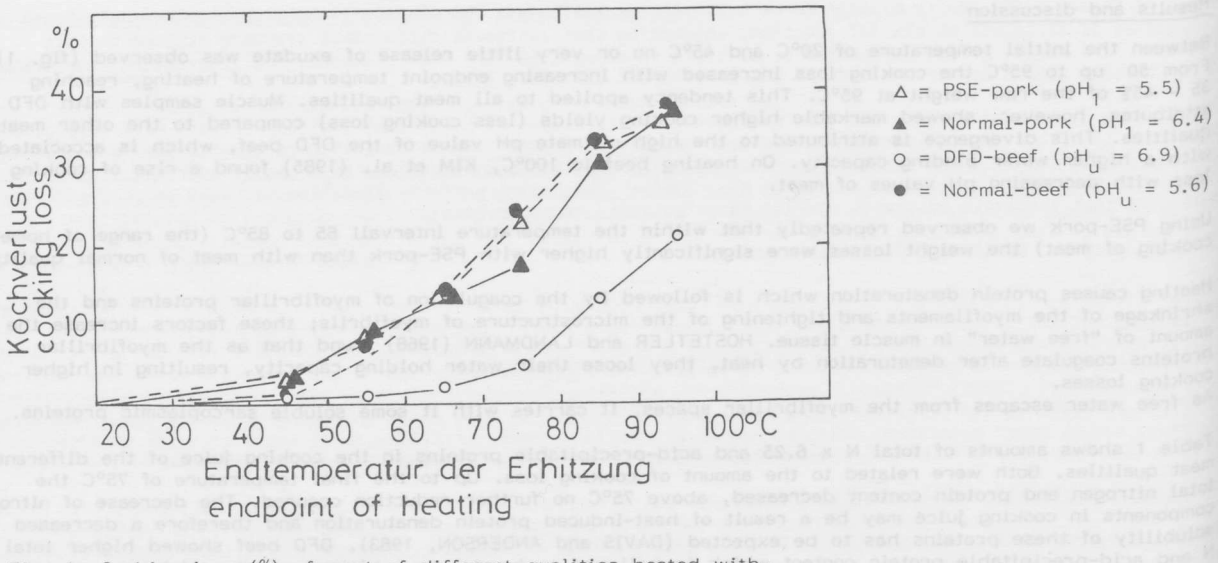

Fig. 1: Cooking loss (%) of meat of different qualities heated with 2.5°C/min from 20°C to final temperatures between 45°C and 95°C

Two separate changes determine apparently the cooking loss of meat. The first phase is associated with the denaturation of the contractile proteins. HEARNE et al. (1978) assume that fibre diameter decreased with heating from 40 to 60°C; this may be due to coagulation of myofibrillar and globular proteins.

The second phase is closely associated with shortening along the meat fibre, forcing out meat juice as shown in fig. 3.

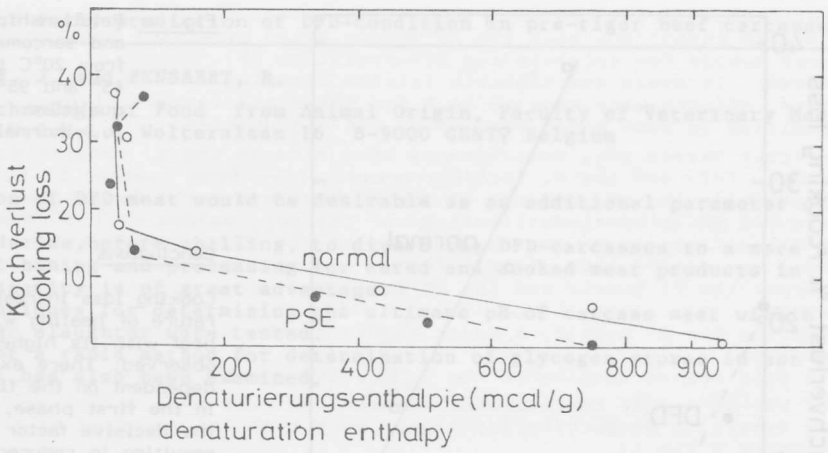

Fig. 2: Relationship between cooking loss (%) and remaining denaturation enthalpy during the heating from 20°C to final temperatures between 45° and 95°C of pork with different quality characteristics.
(o = normal pork;
● = PSE-pork)

There exists a relationship between sarcomere length and cooking loss of pork at different final heating temperatures. It was shown in fig. 2, that the linear relationship between denaturation of proteins and cooking ended at about 15 % cooking loss. In fig. 3 a linear relationship between cooking loss and sarcomere shortening started above 10 % cooking loss, at final temperatures of heating of about 55°C continuing up to 95°C. LOCKER and DAINES (1974) reported that sarcomere shortening on heating may be due to a slight denaturation of the myofibrillar proteins on one hand as well as an initiation of collagen shrinkage. Collagen in meat shrinks at 60-70°C (JUDGE and MILLS, 1986). At this temperature range collagen fibres start to contract. At higher temperatures a part of it is transformed to water soluble gelatine.

In the beginning at low final temperatures of heating sarcomeres seemed to be lengthened with increasing cooking loss. This might be due to a longitudinal weakening of the contractile system. As mentioned above the first phase of cooking loss is associated with denaturation of myofibrillar proteins and a decrease in fibre diameter, the second phase may be due additionally to longitudinal shrinkage of collagen.

In PSE-pork the linear relationship between sarcomere length and cooking loss could be seen in the range of 55-85°C (fig. 3), ending 10°C lower than in normal pork.

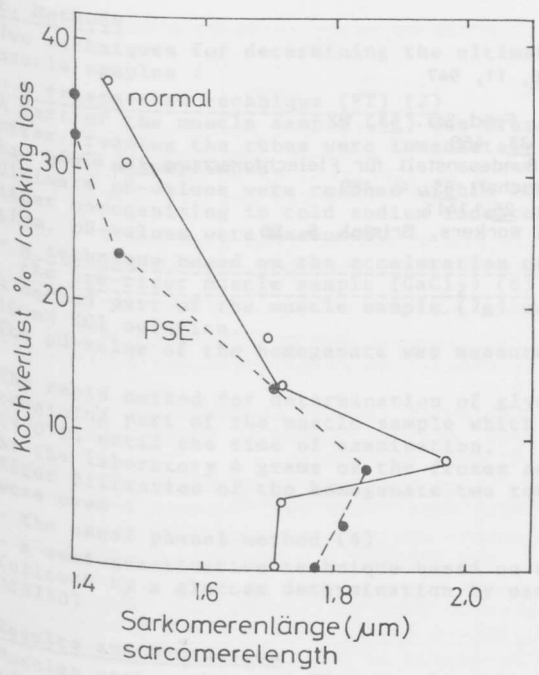

Fig. 3: Relationship between cooking loss (%) and sarcomere length during heating from 20°C to final temperatures between 45° and 95°C of pork with different qualities.
(o = normal pork;
● = PSE pork)

In agreement with these results, investigations performed with normal and DFD-beef exhibited similar changes as in pork (fig. 4). In normal beef the linearity can be noticed above 55°C and in DFD meat only above 75°C. The cause of this difference in initial temperature of longitudinal heat shortening requires further studies.

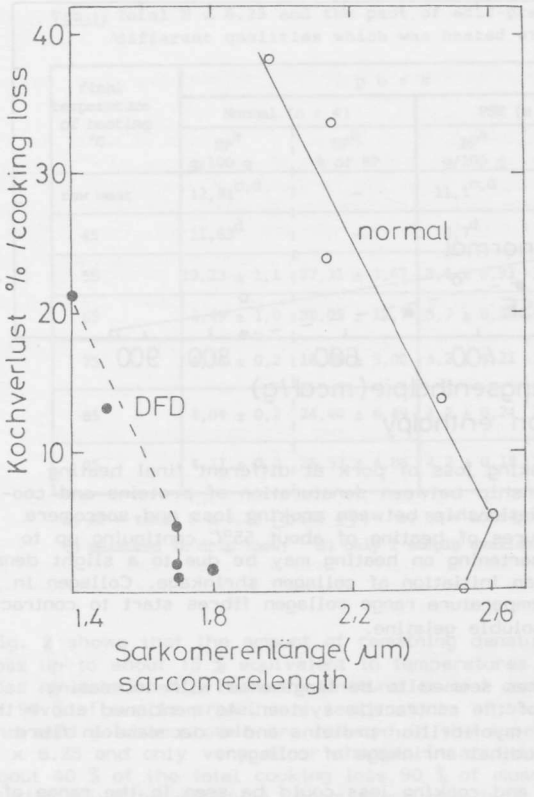

Fig. 4: Relationship between cooking loss (%) and sarcomere length during heating from 20°C to final temperatures between 45° and 95°C of beef with different qualities
(o = normal beef; ● = DFD beef)

Conclusions

Cooking loss increased with increasing final temperature of heating with all meat qualities. In DFD beef with its higher pH, lower cooking losses were observed. There exist two causes of cooking loss dependent on the final temperature of heating. In the first phase, between 20° and about 65°C, the decisive factor is the denaturation of proteins resulting in reduced water holding capacity; in the second phase above 55°C shortening along the muscle fibre occured which might be attributed to heat-induced shrinkage of connective tissue, squeezing water out of the muscle structure. The role of collagen in connection with the cooking loss of meat during heating is not yet sufficiently verified and requires further investigations.

References

DAVIS,C.E. and J.B. ANDERSON (1983), J. Food Protect. 46, 11, 947
HAMM, R. (1977), Fleischwirtschaft 57, 10, 1846
HEARNE, L.E., M.P. PENFIELD, and G.E.GOERTZ (1978), J. Food Sci. 43, 10
HOSTETLER, R.L. and W.A.LANDMANN (1968), J. Food Sci. 33, 468
JUDGE, M.D. and E.W. MILLS (1986), Mitteilungsblatt der Bundesanstalt für Fleischforschung 91, 6768
KIM, C.J., K.O. HONIKEL and R. HAMM (1985), Fleischwirtschaft 65, 4, 489
LOCKER, R.H. and G.J. DAINES (1974), J. Sci. Food Agric. 25, 1411
VOYLE, C.A. (1971); 17th Europ. Meeting of Meat Research Workers, Bristol, S. 95