INFLUENCE OF DIFFERENT CHILLING PROCEDURES ON THE EATING QUALITY OF PORK CHOPS

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SUMMARY

The effect of different chilling procedures on the eating quality of pork chops, in particular tenderness, was investigated on four factories. The chilling procedures varied from a mild traditional batch chilling to an extremely effective tunnel chilling. On each factory a number of pigs with a good water holding capacity (high or medium pH_1-values) and different levels of intramuscular fat were chosen. The longissimus dorsi muscle was removed from each carcass the day after slaughter, divided into two portions (anterior and posterior), and each portion investigated for eating quality using a trained taste panel as well as relevant meat quality characteristics.

The results showed that cold-shortening occurred ~~on~~ in the factory with the most effective chilling process. The average eating quality of the chops from this factory was unsatisfactory with 57% being designated as unacceptably tough.

The decrease in tenderness was especially great in pigs which were most susceptible to cold shortening i.e. pigs with high pH_1-values, but it also occurred in the posterior portion of the loin in some of the pigs with medium pH_1-values. Higher intramuscular fat levels could partially negate the effect of cold shortening.

The anterior portion of the loin was in general more tender than the posterior portion. pH_1-values are however slightly lower in this region of the muscle and it is better protected against the effect of chilling.

Chilling conditions on the factory with best and poorest eating quality were in fact not that different. Process conditions should be arranged so that the time in the tunnel is not less than 60 minutes, if problems with cold shortening are to be avoided.

The factory with cold shortening has never received complaints about tough meat, probably as a result of the number of susceptible pigs (high/medium pH_1-values) being rather low and the intramuscular fat level higher than on the other factories. The chilling conditions are now being adjusted on this factory, so that cold shortening does not occur.

INTRODUCTION

Some preliminary work on eating quality in pork chops seemed to show that there were differences between Danish abattoirs with respect to tenderness, differences which were not due to variations in water holding capacity or intramuscular fat content. Further work confirmed this and showed moreover that variations in tenderness along the longissimus dorsi muscle were related to temperature differences in the meat just after the carcasses left the chilling tunnel. Thus, chilling conditions seemed to be indicated.

Chilling is known to affect tenderness in beef and lamb, where fast chilling can cause the phenomenon of cold shortening. Cold shortening in whole pig carcasses has not in general been considered to be a problem due to among other things fat cover. However, pig meat does have the capacity to cold shorten if conditions are right, eg. hot or warm boned meat with slow glycolysis (Fischer et al. 1980, Støier, 1986).

The aim of this work was, therefore, to investigate the effect of chilling method on tenderness in pork chops. Chilling processes on Danish factories are becoming more effective all the time and it is essential to ensure that this does not lead to a deterioration in eating quality.

MATERIALS AND METHODS

The investigation was carried out on four factories with different chilling conditions - an extremely effective, a long but medium chilling, an average effective chilling and a traditional batch chilling:

Factory	Time on tunnel	Average air temperature	Average air speed	Average temperature fall
1	47 min.	-25.5°C	3.5 m/s	26°C
2	127 min.	-10.0°C	1.5 m/s	28°C
3	60 min.	-24.0°C	3.0 m/s	28°C
4	(25 hrs)	-10°/4°C	0-1 m/s	27°C

The average temperature during equalisation was 4-6°C for the factories with chilling tunnels i.e. factories 1-3.

The experimental material consisted of pigs with high pH_1-values but normal ultimate pH-values, i.e. pigs which would be expected to show cold shortening if conditions are right. Two pH-levels were chosen - high (>6.5) and medium (6.1-6.5) and the pigs had a similar meat content and slaughter weight. In addition, 3 levels of intramuscular fat were used to ascertain any interaction between fat level and chilling process (fat levels below 1.3%, 1.3-1.9% and $\geq$2.0%).

Thus, on all four factories a number of randomly chosen pigs were investigated for pH_1-value at two points in the longissimus dorsi muscle and rigor values were assessed subjectively in the semimembranosus muscle using a scale: 1 = extreme rigor, 2 = in rigor, 3 = slightly in rigor, 4 = relaxed. As far as possible the temperature profile in all pigs was measured across the longissimus dorsi muscle at the same positions as above just after leaving the chilling tunnel - or at the end of the slaughter line for the factory with batch chilling.

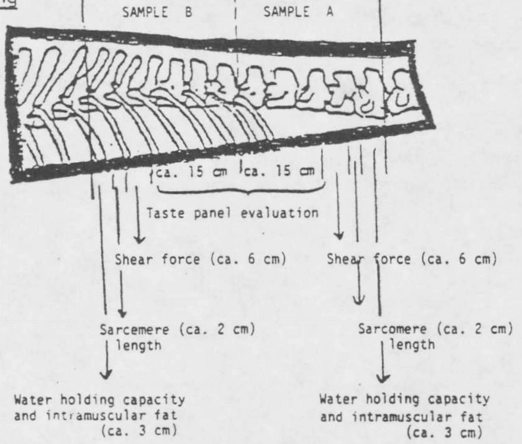
In pigs within the required pH_1-ranges a number of longissimus dorsi muscles of presumed good water holding capacity and varying degrees of marbling were chosen the day after slaughter using the MQM-equipment (Barton-Gade and Olsen, 1984). Only muscles with normal pH_2-values, i.e. below 5.9, were taken into consideration.

The muscle was then divided into two portions, A & B, and samples taken for water holding capacity (soluble sarcoplasmic and myofibrillar proteins), analytical fat content (SBR-method), shear force value (Volodkiewich jaws, 85% penetration), sarcomere length (laser method) and taste panel evaluation (Bejerholm, 1984). The samples for water holding capacity and intramuscular fat content were minced twice and then frozen until the analysis could take place. The remaining samples were vacuum-packed and aged at 2°C until 7 days after slaughter before freezing.

The final choice of samples was based on the results for water holding capacity and analytical fat content. Thus, all samples had a good water holding capacity and similar fat levels at A and B.

The results were treated statistically using an analysis of variance (SAS, 1982) with factory, pH_1/intramuscular fat group and measuring position as variables.

Figure 1. Sampling positions for analysis and taste testing



RESULTS

The results of the analysis of variance are shown in Table 1 and some interactions in Table 2. Factory, pH_1/intramuscular fat group and measuring point all affected taste characteristics in pork chops. There was only one significant interaction (factory x pH_1/intramuscular fat content for flavour).

Influence of factory

Factory 1 had a much poorer eating quality than the others with on average an unacceptable eating quality, mainly as a result of tougher meat. Factory 3 had the best eating quality with factory 2 and 4 intermediate. The percentage distribution in good, acceptable and unacceptable eating quality confirmed the average figures:

	% chops with		
	unacceptable eating quality	acceptable eating quality	good eating quality
Factory 1	57	28	16
Factory 2	12	38	50
Factory 3	9	26	65
Factory 4	11	42	47

57% of the chops from factory 1 had an unacceptable eating quality and only 16% a good quality. For factory 3 only 9% were unacceptable and 65% had a good eating quality.

There were some differences between factories with respect to slaughter line measurements and water holding capacity/pH_2-value, but these differences could not explain the results for eating quality. However, shear force values were higher and sarcomere lengths shorter for pigs from factory 1 than for pigs from the other factories. The results imply therefore that cold shortening has occurred on factory 1.

As expected, the effect was most pronounced for pigs with high pH_1-values and low intramuscular fat levels:

Measuring position	pH_1 level	Tenderness score fat <1.3	fat 1.3-1.9	fat $\geq$2.0
A	>6.5	-2.1	-0.9	-0.2
	6.1-6.5	-1.3	-0.8	-0.1
B	>6.5	-1.9	-0.9	-0.0
	6.1-6.5	-0.2	0.6	1.3

At high pH_1-levels the average tenderness score was unsatisfactory regardless of intramuscular fat level or measuring position. Even the medium pH_1-level showed unsatisfactory tenderness scores for position A. These changes were accompanied by corresponding differences in sarcomere lengths and shear force values (Table 2). Thus, sarcomere lengths were shortest and shear force values highest in meat with high pH_1-values, and position A had shorter sarcomeres and higher shear force values than position B for meat with medium pH_1-values.

Higher intramuscular fat levels could partly offset the negative effects of cold shortening but the average tenderness scores were still not satisfactory even at the highest level in the groups showing cold shortening.

The temperature profile in the longissimus dorsi muscle at the end of the chilling tunnel is shown in Table 3 for pigs with pH_1-values higher than 6.5 together with the corresponding values for shear force and sarcomere length. Pigs from factory 1 had the lowest temperature in the part of the muscle closest to the midline but the highest values further towards the centre of any of the factories and hence the largest temperature difference within the muscle, especially at position A. Factory 3 showed slightly higher/lower temperatures at the above position, while factory 2 and 4 showed a completely different picture. There was a systematic difference in shear force values and sarcomere lengths across the muscle a difference which only partially followed the temperature profile. For position A (the lumbar region) the part closest to the midline had the highest shear force values and the shortest sarcomere lengths. For position B (the thoracic region) the opposite tendency was apparent. These differences are probably due to the position of the carcass in relation to the ventilators during the early part of the chilling process.

Influence of pH_1/intramuscular fat level

As expected, intramuscular fat levels affected taste characteristics to a high degree. The most tender meat with the best flavour was obtained with the highest intramuscular fat level. There was a tendency for the intermediate level to be better than the lowest level but the means were not significantly different in this material.

pH_1-levels on the other hand affected taste characteristics to a much lesser extent, although as previously mentioned, there was an effect of pH_1-level at factory 1, where cold shortening occurred.

Influence of measuring position

The posterior portion of the longissimus dorsi muscle (position A) was less tender and had a lower overall acceptability than the anterior portion (position B). pH_1-values were however slightly lower in the latter region of the muscle and intramuscular fat levels are slightly higher. Sarcomere lengths are also longer at position B, probably as a result of this part of the muscle being best protected from the chilling, combined with possibly a greater degree of stretching.

DISCUSSION

The results of this experiment have shown that cold shortening can occur in intact pig carcasses, if chilling conditions are sufficiently severe - as seems to be the case on factory 1. The higher the pH_1-value and the lower the intramuscular fat content (i.e. the leaner the pig), the more severe the effect. The portions of muscle most exposed to the chilling effect are most affected.

The difference between the temperature profiles in factories 1 and 3 with the poorest and best eating quality respectively was not very large, when the differences in tenderness are taken into account, although the latter correspond to differences in shear force values and sarcomere lengths. However, the process time in the tunnel is different - 47 mins. for factory 1 as against 60 mins. for factory 3. In addition, there are differences in the ventilation system. The ventilators are further away from the carcasses in factory 3, so that the air stream is uniform without large variations in velocity. On factory 1 the air stream is concentrated with speeds of 12-15 m/s immediately under the ventilators falling to zero outside the air stream itself. The reason for cold-shortening on factory 1 but not factory 3 are probably to be found these differences in process conditions

The factory where cold-shortening has occurred has never received complaints about tough meat probably as a result of the number of pigs with high pH_1-values being rather low and the intramuscular fat levels higher than on the other factories. Chilling conditions are now being adjusted on this factory, so that cold shortening does not accur.

Batch chilling was, incidentally, expected to give the best eating quality in pork chops, as the chilling is extremely mild. The results of this experiment show, however, that batch chilling gave an intermediate eating quality and that the best eating quality was obtained with an average effective tunnel chilling. The reason for the intermediate effect of batch chilling on tenderness is difficult to explain from the results of this experiment. Rigor shortening could be a possible reason for the observed effect, but sarcomere lengths were significantly longer with batch chilling so that shortening does not seem to have taken place.

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Table 1. Results of the analysis of variance

LS-means with different superscripts are significantly different. **Taste panel results:** +5 = ideal, 0 = neither good nor bad, -5 = poor.
Significance: NS = not significant, * = p < 0.05, ** = p < 0.01, *** = p < 0.001.

Property	Group						Factory				Position		Significance		
	High pH_1			Medium pH_1											
	low fat	medium fat	high fat	low fat	medium fat	high fat	1	2	3	4	A	B	Group	Factory	Position
No. of pigs	13	24	25	24	24	27	38	30	37	32	136	136			
Rigor (subj.)	3.88^{ab}	4.00^{a}	4.00^{a}	3.68^{b}	3.93^{ab}	3.49^{b}	3.70	3.95	3.85	3.81	-	-	***	NS	-
pH_1-value	6.62^{a}	6.63^{a}	6.62^{a}	6.20^{b}	6.18^{b}	6.16^{b}	6.35^{b}	6.37^{b}	6.45^{a}	6.43^{a}	6.43^{a}	6.37^{b}	***	***	**
Temperature, °C	36.4^{a}	36.7^{a}	36.6^{a}	36.7^{a}	36.8^{a}	37.4^{b}	38.4^{c}	37.3^{b}	38.5^{c}	35.4^{a}	36.8	36.8	*	***	NS
Slaughter weight, kg	65.3^{c}	67.9^{b}	71.1^{a}	67.7^{b}	67.3^{b}	69.4^{a}	70.4^{a}	66.1^{b}	71.2^{a}	65.1^{b}	-	-	***	***	-
MFA-meat %	58.5^{a}	56.5^{bc}	56.7^{b}	58.5^{a}	56.4^{bc}	55.8^{c}	57.3	56.6	57.3	57.1	-	-	***	NS	-
pH_2-value	5.49	5.52	5.54	5.49	5.49	5.48	5.67^{d}	5.47^{b}	5.32^{a}	5.54^{c}	5.51	5.48	NS	***	*
Water holding capacity	0.183^{ab}	0.184^{a}	0.177^{c}	0.186^{a}	0.180^{bc}	0.179^{c}	0.183^{b}	0.180^{a}	0.183^{b}	179^{a}	0.183^{a}	0.180^{b}	***	**	**
% intram. fat	1.04^{c}	1.56^{b}	3.03^{a}	1.06^{c}	1.51^{b}	3.06^{a}	1.89	1.92	1.84	1.87	1.75^{b}	2.01^{a}	***	NS	**
Shear force	98.2^{b}	96.7^{b}	86.3^{a}	101.2^{b}	80.2^{a}	83.8^{a}	117.8^{c}	87.4^{b}	73.5^{a}	85.6^{b}	91.4	90.8	***	***	NS
Sarcomere length	1.85	1.83	1.85	1.83	1.85	1.84	1.75^{c}	1.86^{b}	1.86^{b}	1.90^{a}	1.81^{b}	1.87^{a}	NS	***	***
Fried colour	3.37	3.37	3.46	3.40	3.50	3.52	3.34^{b}	3.39^{ab}	3.49^{a}	3.43^{ab}	3.37^{b}	3.45^{a}	NS	*	*
Flavour	1.06^{c}	1.65^{b}	2.13^{a}	1.38^{bc}	1.48^{b}	2.10^{a}	1.48	1.68	1.83	1.55	1.58	1.68	***	NS	NS
Tenderness	0.93^{b}	0.96^{b}	1.92^{a}	0.94^{b}	1.38^{ab}	1.70^{a}	-0.51^{c}	1.86^{ab}	2.27^{a}	1.59^{b}	1.02^{b}	1.59^{a}	*	***	**
Juiciness	2.34^{c}	2.58^{bc}	2.84^{a}	2.62^{ab}	2.83^{ab}	2.79^{ab}	2.58^{b}	2.44^{b}	3.04^{b}	2.60^{b}	2.65	2.68	**	***	NS
Overall acceptability	0.34^{b}	0.70^{b}	1.59^{a}	0.62^{b}	0.91^{b}	1.53^{a}	-0.44^{c}	1.40^{ab}	1.70^{a}	1.12^{b}	0.75^{b}	1.14^{a}	***	***	*

Table 2. Some average figures for the various experimental groups in relation to factory and position along the longissimus dorsi muscle.

		A						B					
		high pH_1			medium pH_1			high pH_1			medium pH_1		
Factory	Property	low fat	medium fat	high fat	low fat	medium fat	high fat	low fat	medium fat	high fat	low fat	medium fat	high fat
1	pH_1-value	6.55	6.57	6.66	6.17	6.19	6.11	6.50	6.56	6.56	6.10	6.17	6.13
	% intram. fat	0.86	1.35	3.01	1.02	1.48	2.86	1.01	1.84	3.58	1.06	1.56	3.08
	Shear force	153	118	109	137	98	108	149	119	108	120	91	107
	Sarc. length	1.71	1.70	1.74	1.74	1.73	1.76	1.71	1.74	1.76	1.83	1.81	1.82
	Flavour	0.81	1.81	1.75	1.06	1.38	1.70	1.36	1.76	1.92	1.15	0.79	2.22
	Tenderness	-2.11	-0.86	-0.22	-1.26	-0.79	-0.13	-1.86	-0.53	-0.03	-0.15	0.62	1.27
	Overall acc.	-2.00	-0.63	0.02	-1.33	-0.59	0.10	-1.67	-0.41	0.13	-0.26	0.17	1.38
2	pH_1-value	6.63	6.63	6.63	6.23	6.16	6.14	6.48	6.58	6.50	6.13	6.16	6.17
	% intram. fat	1.19	1.36	2.52	0.98	1.54	3.32	1.21	1.63	2.85	1.10	1.69	3.67
	Shear force	94	106	84	100	68	85	88	93	79	95	79	81
	Sarc. length	1.86	1.82	1.86	1.81	1.82	1.85	1.96	1.85	1.89	1.86	1.88	1.89
	Flavour	1.42	2.14	1.78	1.26	1.91	1.92	2.11	1.44	1.44	1.11	1.44	2.22
	Tenderness	1.11	1.69	1.39	0.85	2.18	1.84	1.77	2.19	2.81	1.31	2.31	2.89
	Overall acc.	1.00	1.58	1.06	0.72	1.53	1.62	1.58	1.47	1.86	0.78	1.36	2.25
3	pH_1-value	6.80	6.77	6.66	6.23	6.22	6.15	6.70	6.64	6.66	6.19	6.18	6.20
	% intram. fat	0.96	1.63	2.88	1.08	1.38	2.37	1.10	1.78	3.15	1.18	1.49	3.04
	Shear force	72	68	64	74	74	62	76	77	65	92	83	74
	Sarc. length	1.81	1.83	1.85	1.83	1.83	1.80	1.95	1.89	1.93	1.83	1.88	1.85
	Flavour	0.81	1.86	2.33	1.38	1.41	2.17	1.52	1.84	2.57	2.00	1.72	2.31
	Tenderness	1.85	2.22	2.65	1.95	1.70	1.98	2.93	2.27	3.50	2.32	1.83	2.06
	Overall acc.	0.89	1.78	2.17	1.37	1.11	1.89	1.93	1.56	2.74	1.83	1.33	1.87
4	pH_1-value	6.70	6.70	6.71	6.34	6.22	6.21	6.60	6.60	6.60	6.20	6.12	6.19
	% intram. fat	0.89	1.39	2.75	1.06	1.39	2.69	1.10	1.51	3.55	1.03	1.59	3.47
	Shear force	76	95	94	102	75	79	79	98	89	90	75	76
	Sarc. length	1.85	1.86	1.89	1.83	1.91	1.85	1.98	1.96	1.88	1.88	1.94	1.92
	Flavour	0.56	0.96	2.50	1.56	1.43	2.10	-0.11	1.40	2.74	1.51	1.76	2.14
	Tenderness	1.72	0.26	2.70	1.07	1.24	1.47	2.05	0.44	2.54	1.40	1.98	2.21
	Overall acc.	0.61	-0.02	2.35	0.82	0.80	1.44	0.39	0.31	2.44	1.00	1.56	1.84

Table 3. Temperature profile at the end of the chilling tunnel/slaughter line in relation to variation in shear force value/sarcomere length across the longissimus dorsi muscle.

Position 1 and 5 are respectively closest to and furthest from the midline of the carcasses.

Factory	Property	A					B				
		1	2	3	4	5	1	2	3	4	5
1	Temperature, °C	1.5	12.9	20.3	21.6	20.3	0.3	8.1	14.5	15.5	14.1
	Shear force	141	121	108	116	124	113	111	114	126	142
	Sarcomere length	1.70	1.70	1.72	1.75	1.74	1.76	1.76	1.73	1.72	1.74
2	Temperature, °C	7.1	10.7	13.4	14.7	5.2	7.0	9.8	12.4	13.4	6.3
	Shear force	122	108	90	93	91	77	84	85	88	97
	Sarcomere length	1.80	1.84	1.85	1.88	1.89	1.90	1.90	1.90	1.86	1.89
3	Temperature, °C	2.6	11.8	17.4	17.7	14.7	1.4	8.2	12.8	13.8	5.0
	Shear force	74	66	63	63	71	71	69	67	70	81
	Sarcomere length	1.79	1.83	1.86	1.85	1.86	1.98	1.93	1.91	1.89	1.90
4	Temperature, °C	26.4	32.4	35.0	34.2	32.5	27.3	33.9	35.5	35.1	34.0
	Shear force	104	92	86	85	93	87	88	84	95	102
	Sarcomere length	1.84	1.88	1.88	1.88	1.87	1.95	1.97	1.93	1.91	1.90