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CENTRAL INSTITUTE FOR NUTRITION AND FOOD RESEARCH TNO

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Very quick chilling of calves and pigs

by

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SUMMARY

In several experiments half calf carcasses were chilled either very quickly or slowly. It appeared that very quick chilling at temperatures far below 0 °C lasting some hours induced cold shortening (smaller sarcomere length) resulting in less tender veal.

A comparable quick chilling process had no effect on the quality of pork. For pigs the conditions before slaughtering seem to be more important.

RÉSUMÉ

Refroidage très rapide des carcasses de veau et de porc

Dans quelques expériments des demi carcasses de veau étaient refroidies en partie très rapidement et en partie lentement. Il paraît qu'un refroidage très rapide à une température de -20 °C à -5 °C pendant quelques heures affecte la tendreté du veau par l'action de la contracture provoquée par le froid.

Une méthode comparable pour refroidir des carcasses du porc très rapidement n'avait pas une mauvaise influence. En ce qui concerne la tendreté du porc les conditions avant l'abattage étaient plus importantes.

ZUSAMMENFASSUNG

Schnellstabkühlung von Kälbern und Schweinen

In einer Versuchsreihe wurden Kalbshälften nach dem Schlachten entweder sehr schnell oder langsam gekühlt. Schnelle Kühlung bei Temperaturen weit unter 0 °C während mehrerer Stunden verursachte ein Zusammenziehen der Muskeln, was eine kürzere Sarkomerlänge und weniger zartes Fleisch zur Folge hatte.

Bei einem vergleichbaren Schnellkühlprozess mit Schweinehälften konnte kein Effekt nachgewiesen werden. In diesem Falle waren die fleischeigenen Eigenschaften wichtiger für die Zartheit als der Kühlprozess,

slowly. The tenderness as well as other properties of the veal of both sides were compared.

In pork the post mortem processes proceed much faster than in veal, which means that the chance that cold shortening will appear is much smaller in pigs than in calves. On the other hand, it may be possible to retard the post mortem processes in some degree, in this way decreasing the unfavourable effect of stress and providing a positive result with regard to the meat quality (2). Therefore, the very quick chilling of pigs was also studied.

2. EXPERIMENTAL

2.1. Chilling procedures

The calves and pigs were slaughtered and split into sides at the municipal slaughterhouse at Zeist and then transported to our Institute as soon as possible. The dressed weight of the calves varied from 105 to 120 kg and of the pigs from 75 to 105 kg. After performing the necessary measurements, the right and left sides were chilled either quickly or slowly, as mentioned in table 1. The time between slaughtering and chilling did not exceed 2 hours.

Table 1. Chilling procedures of calves and pigs

animal	treatment	time	temp.	air vel.	rel. hum.
calves	very quick chill	2 h	-20 °C	ca 0.5 m/s	high
		4 h	- 5 °C	2.5 m/s	high
		6 h	- 2 °C	2.5 m/s	high
		12 h	+ 2 °C	2.5 m/s	high
calves	slow chill	18 h	+15 °C	ca 0.5 m/s	ca 60 %
		6 h	+ 1 °C	ca 0.5 m/s	ca 90 %
calves	storage	2-9 d	+ 2 °C	0.5 m/s	90 %
pigs	very quick chill	2 h	-20 °C	ca 0.5 m/s	high
		4 h	- 5 °C	2.5 m/s	high
pigs	moderate chill	2 h	+15 °C	ca 0.5 m/s	ca 60 %
		4 h	+ 1 °C	ca 0.5 m/s	ca 90 %
pigs	storage[1)]	1-13 d	+ 1 °C	ca 0.5 m/s	ca 90 %

[1)] partly vacuum packed after cutting into wholesale cuts

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1. INTRODUCTION

It is known from literature (1, 3) that quick chilling of small animals after slaughtering has an unfavourable influence on the tenderness of the meat. If the temperature of the meat falls below appr. 10 °C before ATP is broken down completely, the muscle fibres will contract strongly. This phenomenon, which is called "cold shortening", results in an increased toughness of the meat.

During the last few years, however, a large number of chilling experiments with calves was carried out in our Institute without any sign of an increased toughness. Moreover, the tenderness of calves exported by The Netherlands has never caused any complaints.

In our experiments the calves were rather heavy, viz. 100-150 kg dressed weight; they were chilled as whole calves. i.e. not split into sides.

The quick chilling process, with an air velocity of 2.5 m/s and a relative humidity of 95 %, was carried out at 0 °C to prevent any freezing of the meat surface. Freezing of the surface of veal actually causes a discoloration and consequently a decrease in commercial value of the carcass. Chilling from 40 °C to 4 °C takes appr. 22 hours for a carcass weight of 100 kg and appr. 33 hours for one of 150 kg.

An EEC-regulation prescribes an internal temperature of maximum 7 °C, before transport to another country may take place. There is a general tendency to speed up the chilling process in order to reduce the cooling time and the delay in transport of the calves. Another advantage is the better keepability of the quick-chilled meat.

The experiments described in this paper were performed to check whether cold shortening will take place when the calves were chilled as quickly as possible, with the restriction that the surface did not freeze. This means that the surface temperature did not drop below -2 °C. Of a number of calves one side was chilled very quickly, the other

2.2. Measurements

During the experiments the following properties were measured (further details are given in tables 2 and 4):

- weight;
- pH in different muscles;
- tenderness of a 2 cm thick slice of meat after cooking; the tenderness was judged by an experienced taste panel of 6 persons, scores: 1 (bad) - 10 (excellent);
- shear force value of a cylinder of cooked meat (diam. 12 mm) with a Warner-Bratzler shear force cell, mounted in an INSTRON Universal Testing Machine;
- sarcomere length by microscopic measurement; for each muscle the mean value of the sarcomere length of eight fibrils was calculated;
- cooking loss of a 2 cm thick slice, vacuum packed in an impermeable pouch after cooking; the veal was cooked for 30 min. at 80 °C, the pork for 60 min. at 70 °C;
- cooking loss of cured meat, measured with a 2 cm thick slice, vacuum packed with a twofold excess of a 3 % brine in an impermeable pouch, cooked after 24 h immersion for 60 min. at 70 °C;
- drip during storage of a 2 cm thick slice packed either on a cardboard tray and wrapped in a PVC-film or in an impermeable pouch.
- meat quality of pork by measuring the transmission value according to Hart, the waterbinding capacity according to Grau & Hamm and according to Wierbicki;
- the time necessary to cut the pig halves into wholesale cuts by an experienced butcher;
- outer colour and appearance, judged by a taste panel, scores: 1-10.

3. EXPERIMENTS WITH CALVES

3.1. Results

The results obtained in chilling experiments with 7 calves are summarized in table 2, together with some experimental details. The total chilling time was 48 hours. Three and ten days post mortem the tenderness, shear force value and sarcomere length were measured in 3 muscles, viz.:

M. longinimus dorsi: front part, centre part and hind part;

M. semimembranosis (hind quarter)

M. triceps brachii (fore quarter).

The hind quarters of 4 calves were examined after 3 days and the for quarters after 10 days; of the remaining 3 calves the fore quarters after 3 days and the hind quarters after 10 days.

The properties which did not show significant differences are not mentioned in the relevant table.

3.2. Discussion

As already known from earlier experiments (4, 5) the weight loss was considerably reduced by quick chilling. This is an important stimulant for slaughterhouses to chill the calves as quickly as possible. The greater yield exceeds the higher costs of quick chilling, compared with a traditional procedure. However, the difference in weight loss between chilling at 0 °C with a high air velocity (2.5 m/s) and the very quick chilling procedure as used in this experiment was very small. With the former procedure it amounted to 1.6 % and with the latter to 1.5 %.

The colour and outer appearance of the calves were much better after quick chilling than after the slow method.

It was quite obvious from the pH-values that the post mortem processes were retarded by very quick chilling. Since the chilling rate is increased by the quick chilling process, the conditions for cold shortening are favourable. It appeared from the other data that cold shortening really took place. Three days post mortem most of the samples of veal were tough and some extremely so. This toughness partly disappeared during ripening but the tenderness of slowly chilled veal was not reached. Even after 10 days ripening some samples were marked by the taste panel with a score between 5 and 6. The shear force values showed the same results (high shear force means poor tenderness).

Cold shortening was most clearly illustrated by the sarcomere length. The average shortening amounts to appr. 25 %. This value remained constant during ripening. Due to the rather large standard deviation and the influence of ripening neither the toughness nor the tenderness can be predicted by the sarcomere length. Moreover

the sarcomere length differs from muscle to muscle, cf. table 3.

Table 3. Sarcomere length, tenderness and shear force value of 3 veal muscles

muscle	chill	3 days p.m.			10 days p.m.		
		sarc. length (um)	tender-ness (score)	shear force (kg)	sarc. length (um)	tender-ness (score)	shear force (kg)
M. long. dorsi, front	quick	1.50	4.9	6.5	1.58	6.9	3.6
	slow	1.96	7.1	3.4	2.06	7.6	2.0
M. long. dorsi, centre	quick	1.63	5.8	5.8	1.53	6.4	4.6
	slow	2.04	7.4	3.0	1.95	8.1	2.1
M. long. dorsi, hind	quick	1.56	5.6	7.3	1.54	7.0	5.0
	slow	2.04	7.7	3.3	1.96	8.0	3.0
M. semimembr.	quick	1.79	5.6	7.4	1.73	6.6	4.4
	slow	2.21	7.6	3.3	2.00	7.5	2.8
M. triceps brachii	quick	1.84	5.4	5.9	1.90	6.8	3.7
	slow	2.17	6.4	4.5	2.38	7.6	3.1

Further studies to establish the optimal chilling conditions, i.e. a short cooling time and complete absence of cold shortening, are in progress.

4. EXPERIMENTS WITH PIGS

4.1. Results

The results of the chilling experiments with 6 pigs together with the experimental conditions are summarized in table 4.

The half carcasses were chilled for 6 hours, either very quickly or at a moderate speed. The pigs were cut into wholesale cuts and the chilling was continued for 18 hours under the same conditions for both sides.

The properties which did not show significant differences are not mentioned in table 4.

The meat was then stored in vacuum pouches.

4.2. Discussion

It is obvious that the situation with pigs is totally different from that with calves. The post mortem processes were already nearly terminated before chilling took place. Consequently, there was a slight influence of the chilling rate on the pH and the weight loss, but no significant effect at all on sarcomere length, cooking loss and shear force value (with only one exception).

However, it appeared that another phenomenon dominated, viz. the rate of pH-fall after slaughtering, which is illustrated in table 5.

Table 5. Influence of pH (2 hours after slaughtering) on sarcomere length, shear force and cooking loss of the M. long. dorsi

pH before chilling (2 h p.m.)	pH after 6 h chilling	sarc. length (um)	shear force[1] (kg)	shear force[2] (kg)	cooking loss[1] (%)	cooking loss[2] (%)
5.8	5.8	1.88	4.28	4.68	22.6	24.3
6.2	6.1	1.99	3.28	3.82	15.9	22.3
6.1	6.2	2.01	4.06	4.15	21.1	24.8
6.0	6.1	1.91	3.98	3.91	26.5	27.5
6.4	6.4	2.02	3.15	4.00	14.8	23.1
6.5	6.2	2.20	2.79	3.55	16.3	21.3

1) after immersion in a brine for 24 h and cooking for 60 min. at 70 °C

2) after cooking for 60 min. at 70 °C

It appeared that there are three groups, viz.:

a. lower pH after two hours, shorter sarcomeres and higher shear force than group b;
b. intermediate group;
c. higher pH after two hours, longer sarcomeres, lower shear force and less cooking loss than group b.

The first and second groups seem to be identical with PSE-pork, but this has not been verified. Even between the individual pigs there

was no difference in properties between the very quick-chilled sides and the moderately chilled sides. It can be concluded, therefore, that very quick chilling has no effect on the meat quality of pigs, even in the case that the meat was PSE.

In figure 1 the trend of different properties of the M. long. dorsi is shown. It appeared that there were remarkable differences with a minimum somewhere at one third from the front, between the shoulder chops and the rib chops, and a maximum at two third from the front, between the rib chops and the loin chops. (It should be noted that the sarcomere length has been drawn on a reversed scale.) This trend makes it necessary to take a number of samples equally distributed over the M. long. dorsi.

5. CONCLUSIONS

From the experiments with the very quick chilling of calves and pigs the following conclusions can be drawn:

- Very quick chilling at temperatures far below 0 °C for some hours has an unfavourable effect on the tenderness by inducing cold shortening.
- The cold shortening was most clearly observed by measuring the sarcomere length. However, due to the post mortem ripening processes the tenderness cannot be predicted by means of the sarcomere length.
- Very quick chilling of pigs at temperatures far below 0 °C for some hours has no adverse effect on the meat quality. Other properties of the meat, especially the rate of pH-fall post mortem, however, are very important for the tenderness.

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Table 2. Influence of chilling rate on the properties of veal

property	experimental conditions	very quick chill	slow chill	difference
weight loss	during 48 h	1.5 ± 0.6 %	2.8 ± 0.3 %	95 % sign.
outer colour and appearance	24 h p.m.	8.2 ± 0.4	6.9 ± 0.4	99 % sign.
	48 h p.m.	7.7 ± 0.5	6.8 ± 0.2	99 % sign.
	10 days p.m.	6.7 ± 1.2	6.2 ± 0.7	not sign.
pH (mean of 4 measurements in different muscles)	24 h p.m.	5.9 ± 0.3	5.6 ± 0.1	99 % sign.
	48 h p.m.	5.6 ± 0.1	5.6 ± 0.1	not sign.
tenderness[1] (mean of 5 measurements)	3 days p.m.	5.5 ± 1.0	7.3 ± 0.7	99 % sign.
	10 days p.m.	6.8 ± 0.8	7.8 ± 0.4	99 % sign.
shear force value[1] (mean of 5 measurements)	3 days p.m.	6.6 ± 1.9 kg	3.5 ± 1.0 kg	99 % sign.
	10 days p.m.	4.2 ± 1.6 kg	2.6 ± 0.7 kg	99 % sign.
sarcomere length (mean of 5 measurements)	3 days p.m.	1.7 ± 0.2 um	2.1 ± 0.3 um	99 % sign.
	10 days p.m.	1.7 ± 0.2 um	2.0 ± 0.2 um	99 % sign.

[1] after cooking for 30 min. at 80 °C

Table 4. Influence of chilling on the properties of pork

property	experimental conditions	very chick chill	moderate chill	difference
weight loss	during 0- 6 h	1.22 %	1.22 %	not sign.
	during 6-24 h	0.73 %	1.02 %	95 % sign.
pH (mean of 4 measurements in different muscles)	before chilling	6.2	6.2	no diff.
	after 6 h chilling	6.2	6.0	
shear force value	1 day p.m.[1)]	4.2 kg	3.9 kg	95 % sign.
M. long. dorsi	2 days p.m. after immersion in a brine[1)]	3.5 kg	3.6 kg	not sign.
M. semimembr.	2 days p.m.[1)]	5.4 kg	5.3 kg	not sign.
M quadriceps femoris	9 days p.m.[1)]	2.5 kg	2.8 kg	not sign.
sarcomere length M. long. dorsi (mean of 6 chops)		2.00[4] um	2.007 um	not sign.
cooking loss (mean of 6 samples)	1)	21.0 %	21.5 %	not sign.

1) after cooking for 60 min. at 70 °C

Figure 1. Trend of different properties in the M. long. dorsi of pigs