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Effect of Rate of Chilling on Structure of Pork Meat

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The effect of rate of chilling on the quality of pork carcasses has been a matter of discussion in the meat industry for a long time. After the introduction of refrigeration it was a widespread belief in the meat industry that rapid cooling caused the meat pores to close on the surface with a resultant imprisonment of the animal heat in the interior of the carcass (5).

Improper cure in hams and bacon were attributed to the "closed" nature of the muscle structure so it was therefore customary to permit the carcasses to hang over-night at room temperature before placing them in the cooler.

In cause of his work with "open" and "closed" structure of pork meat Callow (6) found that the rate of cooling and pH had effect on the structure. The "open" structure, which gave a rapid penetration of salt into the meat was developped when the "ultimate" pH was low (usually below 5.8) and the cooling was slow. When rapid cooling was applied the structure became "closed" regardless of the pH. Brooks et. al. (4) in a practical curing experiment with Wiltshire bacon, however, found no evidence for rapid cooling being detrimental to the meat quality.

There has, however, in recent years appeared a number of observations (2, 8, 9) that anaerobic glycolysis frequently occur very rapid in pork muscle. The result is that the meat attains a considerable acidity while the body heat still remains in the carcass and consequently the meat becomes pale and watery. The purpose of this experiment is to determine if it is possible through as rapid cooling of the carcasses as appears possible under plant conditions to control the rate of pH fall in the carcass and the effect of the acid formation on the quality of the processed meat.

Experimental

Animals and chilling method. The experimental material consisted of 9 Landrace pigs of known breeding and feeding regimen. The pigs were slaughtered in two groups of three each at the Roskilde bacon factory. After scalding and singeing about 30 minutes after sticking, the carcasses were eviscerated and split. The one side was weighed, wrapped in a polyethylene bag after resistance thermometers had been placed in muscles at various places in the side. Fig. 1. The air was removed from the bag be means of a household vacuum cleaner to eliminate air pockets. The wrapped side was then fully immersed in a vat containing circulating brine which was kept at a temperature of -2°C through cooling coils placed in the bottom of the vat. Fig. 2. The temperature of

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-2°C was chosen in order to produce a maximum chilling rate without risk of partial freezing of any part of the side. The brine cooling was carried out until the part of the side (ham center) which chilled most slowly had reached a temperature below 20°C. That lasted about 4 hours. On figure 3 is an example of the chilling rates in the different parts of the side. For comparison gives figure 4 the corresponding rates in the control side. The sides were then taken out of the bag and placed in a chilling room (Danish Meat Research Institute) with an air temperature of +3°C. The control side was retained on the slaughter line and placed in the same chilling room in a normal commercial sequence. Right and left sides were equally distributed in the experimental and control groups. 24 hours after slaughter the sides were taken out of the chilling room, weighed, and a sample taken out of the loin at the lumbar region for evaluation of color and water holding capacity of the meat.

Processing of the meat. The control and experimental sides were fabricated into hams, shoulders, and loins. These cuts were stich pumped with a 19°B pickle containing salt, $NaNo_3$, $NaNO_2$ and sodium tripolyphosphate. The quantity of pickle pumped into the cuts corresponded to 8 % af their weight. The cuts were tank cured for 3 days and matured for 5 days. They were then boned, trimmed and packed in cans corresponding to the weight of the cuts and the cans were evacuated. For hams and shoulders pear shaped cans were used, for pork loin 2 lbs. cylintrical cans.

The cans were given a heat treatment until the center reached a temperature of 66°C. The cans were examined after 1 month storage at 4°C. Sausage emulsion was made from the tenderloin, belly meat and meat trimming from shoulder and loin. There were made two batches for each 3 carcasses, one of the meat from the experimental sides, one of the meat from the control sides. For the two batches made from the carcasses in the first group was used a standard recipe of 7 kg lean meat, 4 kg lard, 5 kg ice-water. The emulsion was packed in 7 oz. cylintrical cans and sterilized at 108°C for 60 min.

For the two batches made from the carcasses in the second group a quantity of 320 g milk powder was added to the recipe. The inclusion of milk poweder would illustrate if addition of an emulsion improving additive might influence the effect of differences in the meat quality on the finished product quality.

Analytical methods. Besides weighing the sides and the cuts during chilling and processing, temperature and pH were also determined during the chilling of the carcasses. For pH determination a pH meter, Radiometer model 24, and a continuous registering pH meter (Radiometer model 31, electrode-selector ELS 31 electronic recorder type 153 (Honeywell)) were used. The color of the fresh loin surface was evaluated by means of a reflectance photometer, Carl Zeiss model ELREPHO, filter R 53, with magnesium oxide as a standard white surface. The intensity of light reflected from the meat surface in per cent of the intensity of light reflected from the magnesium oxide was used as a measure of meat color. This percentage is hereby termed the color index. A low value indicates a dark color. The color index was determined not only on the fresh meat but also on center slices

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of the cured meat products. Readings were made at standard points on the slices and the average taken. The water holding capacity was measured as explained earlier (Wismer-Pedersen 1959). The water holding capacity is expressed in the LW number, which gives the amount of water in mg which can be pressed out of 1 g of meat under standard conditions. A high LW number denotes an inferior water holding capacity.
Organoleptic evaluations of the canned products were conducted by a panel of 6 to 7 members. The scoring was made with a scale of 10 scores. 10 denoting excellent, 8 good, 6 minor quality defficiency, 4 quality defficiency, 2 strong quality defficiency and 0 extremely bad quality. In the scores for salt taste + denote deduction for too salty, and - for too fresh. The percentage of jelly in the can was determined. Salt content of the meat was determined by precipitation with silver nitrate (1) and the nitroso-haem pigments were estimated as done by Hornsey (7).

Results and discussion

The chilling and its effect on pH

When the chilling of the sides in the refrigerated brine was applied it was possible to accelerate the rate of chilling as shown on figure 3. It required less than 4 hours for the ham center to reach 20°C compared to 6 hours for the control sides. In the chilling room where the control sides were chilled the air temperature was held at about 3°C during the chilling period without forced air circulation. During commercial operations forced air circulation and lower air temperatures are customary. Due to the fact that the chilling room was only filled to a small fraction of its capacity, the chilling rate of the sides simulated, however, what is common under commercial conditions. The brine cooling was terminated when the ham center had reached a temperature of 20°C. Model experiments (3) had indicated that effect of low pH values on the color and water holding capacity was substantial only when the meat temperature was above 20°C.

The pH recordings showed a distinct difference in pattern in relation to the chilling rates. As indicated earlier (11) there are four distinct types of post-mortem pH patterns which may be recorded in pork muscle. Each of these has a special effect on development of the meat structure. In this experiment we have pH pattern no. 2, 3 and 4 represented. Pattern 2 denotes a gradual decrease of pH to approximately 5.7 at 8 hours with an ultimate pH of 5.3 - 5.7. Pattern 3 denotes a relatively rapid decrease to approximately 5.5 at 3 hours with an ultimate pH of 5.3 to 5.6. Pattern 3 denotes a sharp decrease to a pH of approximately 5.1 at 1½ hour and a subsequent elevation to 5.3 - 5.6. Im table 1 is given the types of pH patterns recorded in the loins with LW values and color index of the meat. It is notable that the rapid chilled sides have type 2 and 3 while all the normal chilled sides except one had type 4 pH pattern. As a result there is a highly significant difference in the LW values between the two rates of chilling. The average color index for the rapid chilled sides is lower than for the normal chilled sides showing that the meat color is darker. The pH values at ½ hour after slaughter were rather uniform around 6.4 except for carcass 1 and 5 where the pH had dropped to 5.90 and 5.55 respectively. This rapid pH drop resulted in very poor water holding capacity and pale color when the sides were normally chilled. For the rapid chilled sides the

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water holding capacities of the meat from these carcasses were quite good and the effect of the initial rapid drop in pH only showed a rather pale color of the meat from carcass 5.

Curing and the cured products

The average loss in weight of the sides submitted to the brine chilling was 0.06 % compared to 0.62 % when the sides were chilled in the normal way. The substantial reduction in the chilling loss appear however partially due to the sides were wrapped in the polyethylene bag during the brine chilling. In table 2 are given the average net gains in weight during cure of the hams and shoulders, the salt contents of the meat and the percentage of jelly cooked out of the meat during the heat treatment. The percentage is calculated on basis of the weight of the meat before the heat treatment. One notices that the cuts from the rapid cooled sides gained less in weight during cure and the salt content was lower compared to the cuts from the normal chilled sides. The reason appears to be that the rapid chilling has produced conditions similar to Callow's "closed" structure. It has furthermore been observed (10) that pork cuts with high LW values absorb more pickle than cuts with low LW values. The percentages of jelly in the cans are generally lower for the cuts from the rapid cooled sides. Due to the difference in the absorption of pickle not much interest can be attached to the difference. Interest might on the other hand be given the difference in percentage cooked out jelly, including fat, for the two sausage preparations. For both recipes the rapid chilling of the sides had increased the water binding property of the meat. For both recipes the reduction in jelly content was highly significant ($P < 99.95$ %).

In table 3 appear the average results from the evaluation of the organoleptic quality of the canned products. It appears from the scores that the panel could not on an average find any notable difference in the quality of the products in relation to the chilling rates. An exception was texture which were found slightly inferior for the products made of the cuts from the rapid chilled sides. Statistical analysis of the taste panel scores revealed, however, highly significant differences between the panel members in their scoring, some prefering the products from the rapid chilled sides and some those made from the normal chilled sides. The color index showed that the meat color was slightly darker when the products were made from the rapid chilled sides, except for the shoulder. The muscles in the shoulder cut are, however, rather inhomogeneous and contain fairly high quantities of fatty tissue. These muscles appear to respond different to the rates of chilling from what the loin and ham muscles do, as also noted from the results in table 2. Estimation of the formation of the nitroso-haem compound in the cured meat products revealed no considerable difference in relation to the chilling rates. Examination of the quality of the sausage products revealed no difference in relation to the chilling rates apart from the quantity of cooked-out jelly.

Conclusion. The increased rate of chilling effected through the brine chilling increased the binding capacity of the meat through

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control of the rate of the post mortem pH fall and possibly by reduction of the impact of acidity on the meat proteins. From the taste panel observations may be concluded that no definite improvement of the quality of the canned meat products was achieved through the increased chilling rate. However, a definite reduction of the cooked-out jelly was obtained as far as the emulsion products are concerned.

Summary

In order to control the development of watery pork structure experiments were made with rapid chilling of split pork carcasses. The chilling was performed immediately following the evisceration of the carcass. The pork sides were wrapped in a polyethylene bag and immersed in refrigerated brine at -2°C. The chilling was terminated when the ham center reached a temperature of 20°C, which required slightly less than 4 hours compared to 6 hours for the control sides. The increased rate of chilling retarded the intensity of the post-mortem pH fall with the result that the color and water holding capacity of the meat was materially improved. From the rapid and normal chilled sides were processed cured, canned hams, shoulders and loins, as well as sausage emulsions. Examination of these products did not reveal any definite improvement of the quality in relation to the increased rate of chilling. The amount of cooked out jelly in the sausage products was, however, significantly reduced when meat from the rapidly chilled sides was used.

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Table 1

Color and water holding capacity of fresh loin muscle in relation to pH and rate of chilling

Carcass no.	pH ½ hour after slaughter	normally chilled side: pH 24 hours after slaughter	pH pattern type	LW	Color index	rapidly chilled side: pH in loin 24 hours after slaughter	pH pattern type	LW	Color index
1	5.90	5.40	4	507	22.8	5.50	3	456	18.2
2	6.35	4.45	4	475	19.9	5.65	2	459	18.3
3	6.45	5.60	4	490	20.3	5.60	3	436	16.7
4	6.45	5.55	4	479	23.0	5.60	2	431	17.8
5	5.55	5.58	4	506	32.8	5.48	3	442	26.5
6	6.45	5.42	3	461	19.5	5.65	2	383	17.4
Average		5.50	-	486	23.1	5.58		435	19.2

Table 2

Average weight gain during cure, salt and jelly content of the canned products

	Chilling rate of the sides	Net weight gain during cure in %	Salt content of the finished product %	Cooked-out jelly in the can %
Hams	rapid	6.07	2.47	9.2
	normal	6.62	2.54	9.9
Shoulders	rapid	5.67	2.96	8.6
	normal	7.03	3.17	7.8
Pork loin	rapid	-	2.41	12.5
	normal	-	2.60	12.9
Sausage preparation I	rapid	-	-	34.6
	normal	-	-	38.6
Sausage preparation II	rapid	-	-	19.3
	normal	-	-	21.0

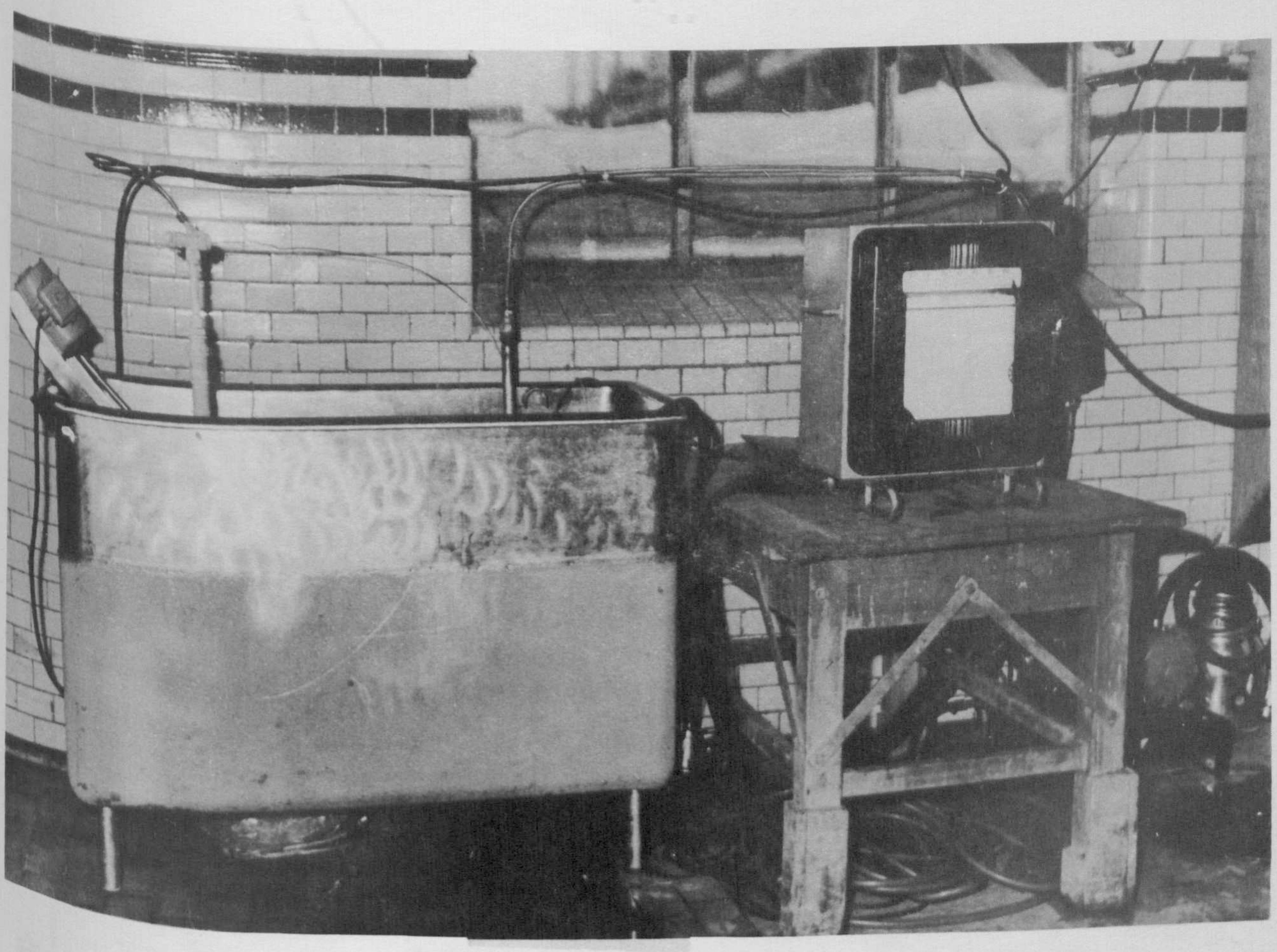
Table 3

Average results of the organoleptic examinations of the canned products

	Chilling rate of the sides	Color score	Saltiness score	Taste score	Texture score	color index *
Hams	rapid	6.8	- 9.53	7.7	7.5	29.0
	normal	6.6	- 9.52	7.6	7.9	31.3
Shoulders	rapid	7.4	+ 9.54	7.8	7.6	20.3
	normal	7.7	+ 9.54	8.1	8.0	18.8
Loin	rapid	6.9	- 9.44	7.2	7.2	35.3
	normal	6.7	- 9.36	7.2	7.5	41.2

* average of three samples

Figur 1



Figur 2

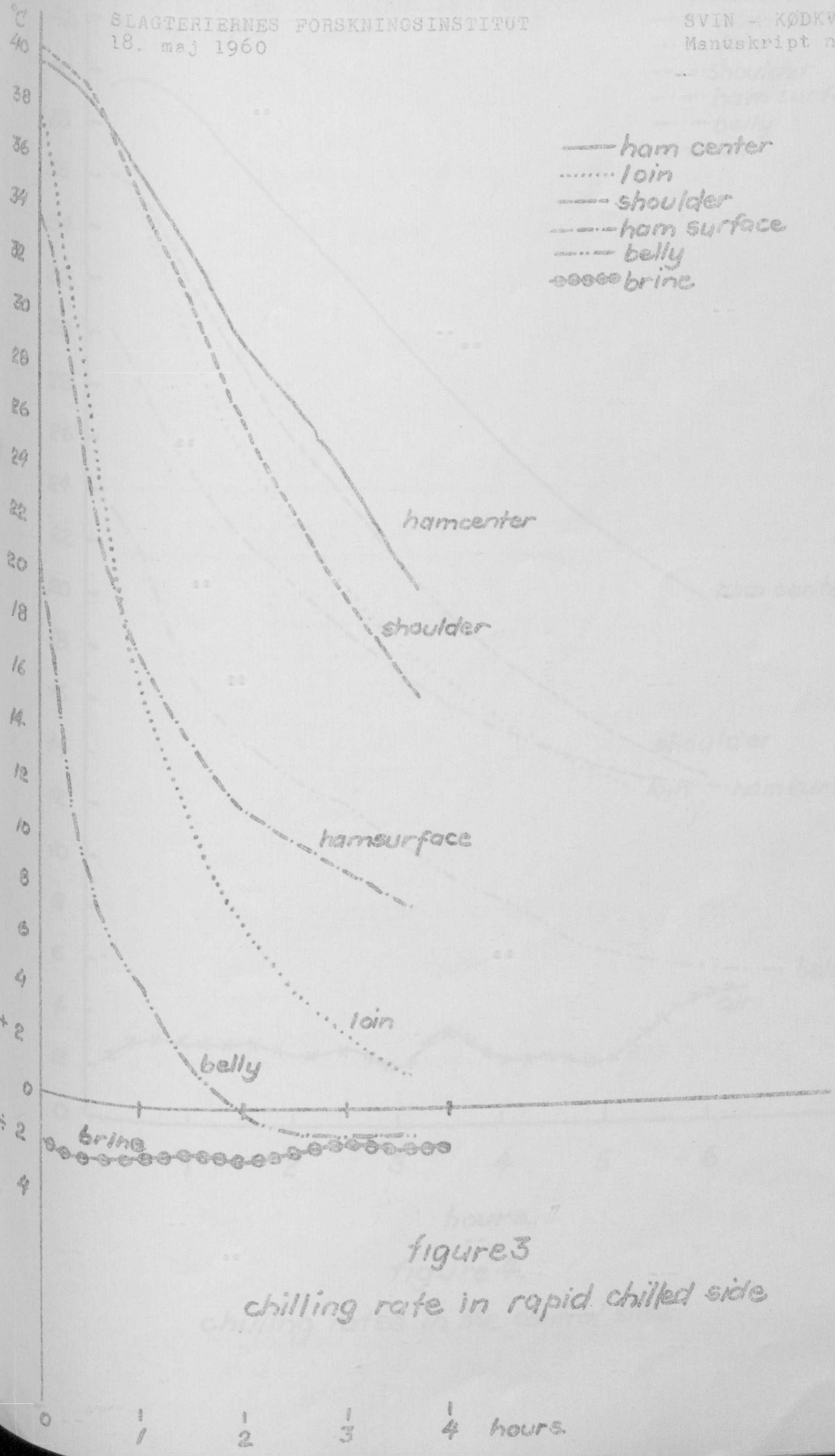


figure 3
chilling rate in rapid chilled side

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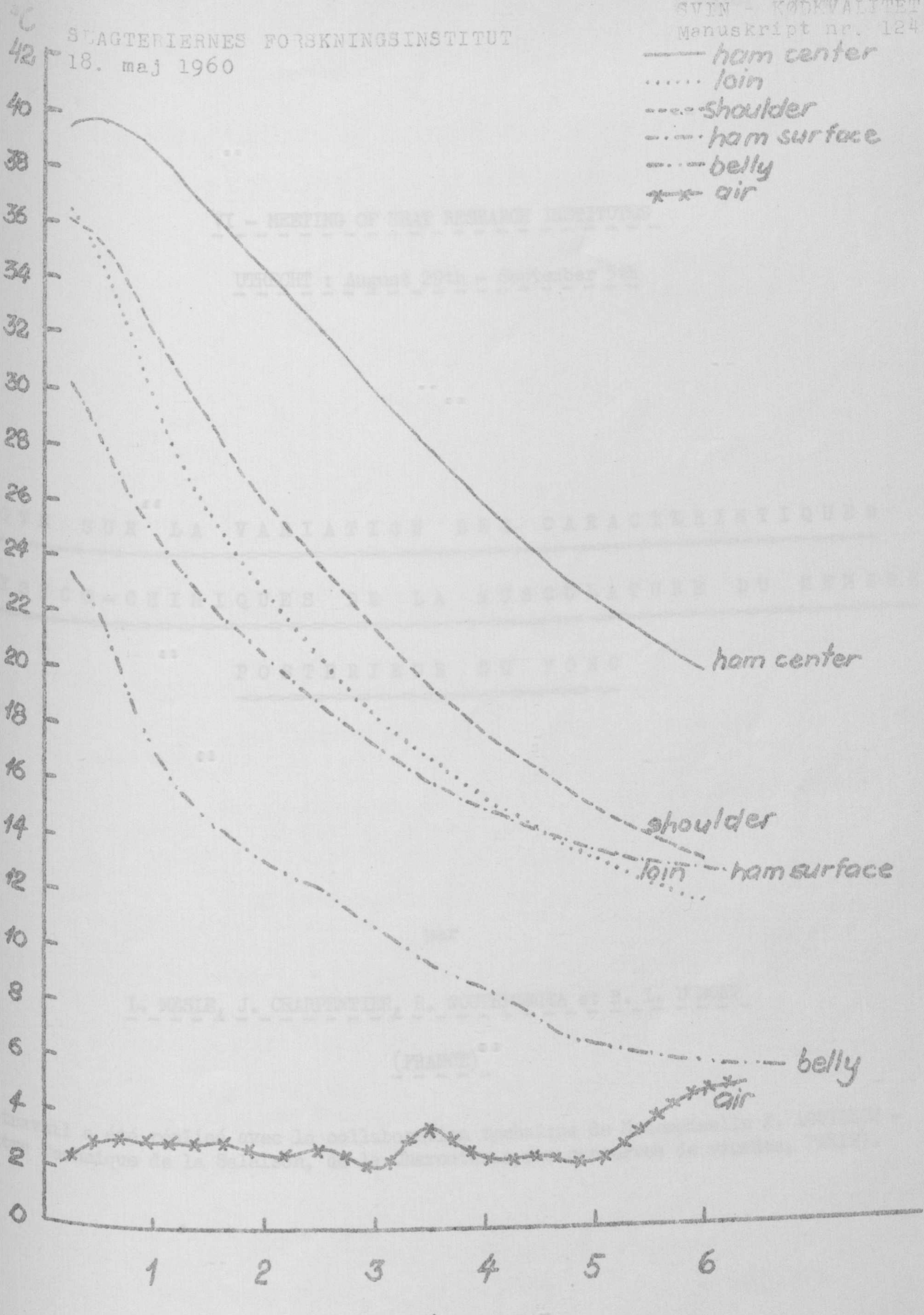

figure 4.

chilling rates in the control side