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Pre-slaughter temperature and its effect on the post-mortem metabolism in pig muscle

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Introduction

The temperature of the carcass plays an important role in the post-mortal enzymatic processes (Bendall et al, 1963). Briskey and Wismer Pedersen (1961) stated that a rapid pH fall was related to heat development. Ludvigsen (1953) already mentioned high temperatures (45° C) in carcasses with degenerated meat.

A logical consequence of this was that depressing the body- and the meat temperature by cooling prevented bad meat quality.

In the 1962 report of the Danish Meat-research Institute the importance of cooling is mentioned in cases of a too rapid pH fall at a too high temperature.

Hart and Sybesma (1964) showed that removing the back fat layer of one side immediately after slaughter had an improving effect on the meat quality. Kastenschmidt et al.(1964) affected the temperature in the meat by pre-slaughter treatments i.e. applying cold water (1-3° C) and hot air (42-48° C). In pigs under alternating warm and cold circumstances the meat temperature was low while under hot circumstances the meat temperature was high. The first category showed dark and firm muscles, the high temperature induced a rapid pH fall and pale, soft and exudative meat.

Under these both extreme circumstances the rigor mortis developed very soon.

In the danish report (1962) the transport effect on temperature is mentioned. The body temperature rose about 0.6° C during transport.

Harling (1955) found high body temperatures directly after the transportation which decreased after a period of rest.

Bendall (1965) supposes that the excessive numbers of nervous stimuli on the muscles are more important as a cause of a high rate of pH fall than an eventually existing high temperature.

However excitation leads very often to muscle tension and contractions by which much heat can be developed.

Pigs with a high muscle percentage will proportionally, when contracting, produce in total more heat.

Ilancic and coworkers (1965) found higher body temperatures in lean pigs which should be caused according to these authors by a higher intensity of metabolism.

1.1. The goal of the investigation

We wanted to evaluate the relation between the pre-slaughter temperature of pigs and their meat quality. Therefore we studied the effect of exercise on the body temperature of different breeds, the relation between pre-slaughter and post slaughter temperature and furthermore, the relation between different quality criteria i.e. onset of rigor and rate of pH fall and the meat temperature.

2.0. Material and Methods

2.1. Temperature measuring

We used the Ellab meter type TE 3 (thermo couple principle) with the rectal electrode RQ 1 and the needle electrode KP 1. The meat temperature (needle electrode) was measured about 40 minutes post mortem in the M. adductor and in the M. semimembranaceus. The length of the electrode is 3 cm., so the recorded meat temperature is the temperature 3 cm. below the meat surface.

2.2. Rigor measuring

The rigor measuring was carried out with an apparatus which is described by Sybesma (1966). With this apparatus we could reliably discriminate between the complete rigor mortis (III), the onset of rigor (II) and the pre-rigor state (I) on a fixed moment after death.

2.3. pH-measurements

The pH was measured with needle electrodes connected with the portable Philips (PR 9401) meter.

3.0. Experiments and Results

There were 4 different types of experiments:

3.1. The effect of exercise on the body temperature

3.2. The relation between the pre-slaughter temperature and the meat temperature

3.3. The effect of environmental factors on the meat temperature

3.4. The relation between the meat temperature and the meat quality

3.1.0. The effect of exercise on the body temperature

One can imagine that hypertrophic musculature during exercise produces more heat because more contractile tissue is involved. So the heat load might be more severe for pigs with a high leanness which could probably result in a higher body temperature. To test this hypothesis we collected rectal temperature data from two breeds, which were fattened in the same barn, on the moment of the weekly weighing (table 1).

Table 1

Rectal temperature after excitation

Piétrain			Large White		
Compartment	n	T (°C)	Compartment	n	T (°C)
I	4	40.2	IV	10	39.8
II	9	40.2	V	10	39.5
III	8	40.1	VI	5	39.5
X	8	40.2	VII	4	39.4
XI	10	40.0	VIII	9	39.8
Total	39	40.1 ***	IX	9	39.8
			Total	47	39.6 ***

$P < 0.001$

There is a considerable difference in temperature although the pigs were clinically healthy. From other data we had enough evidence to suppose that in rest there was not such a difference in body temperature between the breeds. Because the animals had to walk to the central spot for weighing the increase in temperature is likely to be caused by muscle exercise and excitation.

3.2.0. The relation between the pre-slaughter temperature and the meat temperature

It seems logically that animals with a high rectal temperature on the moment of death will also have a high meat temperature. But it

is also possible that heat is developed independently after slaughter. One of the first questions is what we have to consider as too high a temperature. Arbitrarily we can handle the 40° C as the limit for rectal temperature (Harling, 1955). For the meat temperature limit we have chosen 41° C. In one experiment with two groups Dutch Landrace pigs temperature was measured just before and 40 minutes after killing. In table 2 the data and correlations are given.

Table 2

Pre- and post-slaughter temperature and the relation between each other

	n	t. rectum	t. meat	r
group A	47	39.3 (37.6-41.4)	40.5 (39.3-42.4)	0.60 **
group B	50	39.9 (37.9-41.9)	41.2 (39.8-43.0)	0.81 **

** $P < 0.01$

From 97 animals, 28 had a rectal temperature of 40° C or higher. From these 28 pigs, 25 (90 %) had a meat temperature of 41° C or higher.

Putting it the other way round, we can calculate the percentage of pigs with a high meat temperature which also had a high pre-slaughter temperature. From the 42, the already mentioned number of 25 or about 60 % passed the limit. However when we lower the pre-slaughter limit till 39.5° C, 35 pigs i.e. 83 % have a meat temperature $\geq$ 41° C. The 12 pigs with a meat temperature $\geq$ 42° C were all pigs with a rectal temperature $\geq$ 40° C.

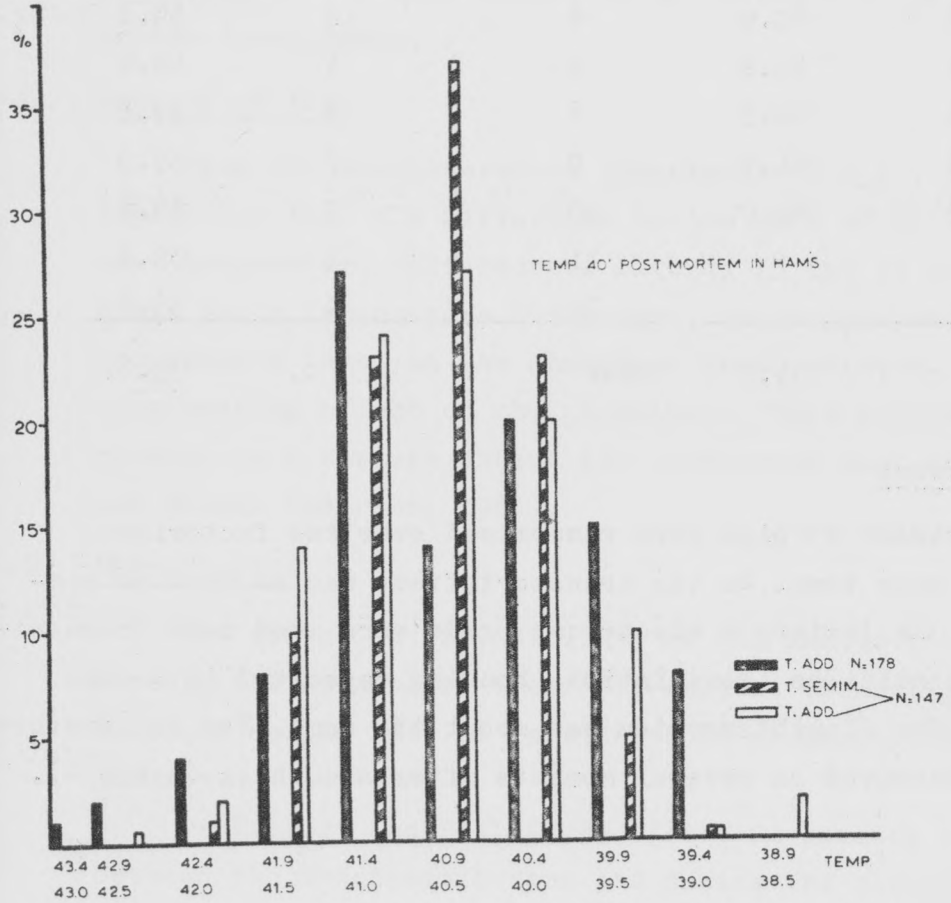
These results indicate that in farmost cases the high meat temperature is determined by a high rectal temperature.

3.3.0. The effect of environmental factors on the meat temperature

3.3.1. Transporteffect

In one slaughterhouse in several hundreds of pigs (Dutch Landrace) the meat temperature was measured. A frequency distribution is given in figure 1.

figure 1 Frequency distribution of ham temperatures measured 40 minutes post mortem



No systematically difference could be found between the temperature in the M. adductor and the M. semimembranaceus in the same ham. It was possible to check the origin of the pigs as to transportation and farmer.

We found that between two transportgroups the meat temperature differed very much while the lots of pigs from different farmers within the transport groups had about the same temperature. (table 3).

Table 3

Transportgroups and meat temperature differences

Transport A			Transport B		
Farmer no.	number of pigs	T 40 '	Farmer no.	number of pigs	T 40 '
1	8	40.9	6	12	39.8
2	2	41.2	7	4	40.4
3	6	40.3	8	3	39.8
4	9	41.5	9	7	39.9
5	5	41.0	10	7	39.8
			11	2	39.6
			12	9	39.6
Mean		41.0	Mean		39.8

3.3.2. Slaughterhouse-effect

In one experiment 45 pigs were randomised over two factories (A and B) in the same town. So the transporteffect was as much as possible eliminated. In factory A electrical prods were used more frequently. The housing conditions (ventilation, housing capacity) in A were worse than in B. The slaughtersystem was about the same. The temperature and pH fall was measured on several moments after slaughter (table 4).

Table 4

Slaughterhouse differences

Factory A			Factory B		
Time post mortem	Temp.	pH	Time post mortem	Temp.	pH
16 min.	41.3 **	-	13 min.	40.4 **	-
43 min.	40.9 **	6.02 ''	41 min.	39.9 **	6.25 ''
386 min.	21.6	5.78 '	381 min.	22.9	5.94 '
18 hours		5.70	18 hours		5.79

** and '' $P < 0.01$

' $P < 0.05$

We got evidence that the conditions (housing, treatments) in factory A induced a higher meat temperature and post mortem rate of pH fall.

It is obvious that transport and factory conditions before slaughter are contributory causes of high meat temperatures.

3.4.0. The relation between the meat temperature and the meat quality

As criteria for the meat quality we have chosen the pH, 40 minutes postslaughter as an expression of the rate of pH fall and the rigor-measuring on the same moment as an indication for the rate of rigor mortis development.

3.4.1. Rate of pH fall

From the slaughterhouse experiment (3.3.2., table 4) we got the impression that the difference in the rate of pH fall is induced by the meat temperature differences. Already 13 and 16 minutes after killing there was a temperature difference, so one can understand that a higher temperature level on the moment of death existed. This might cause an accelerating effect on the glycolysis. This acceleration possibly increases to a certain extent the postmortal heat development (Briskey and Wismer Pedersen, 1961).

3.4.2. Rigor mortis

The change in extensibility of the muscle fibers follows very closely the changes in their ATP-content (Bendall, 1965). A rapid onset of rigor mortis must be considered as an indication for a bad meat quality.

De Fremery and Pool (1959) found in poultry a close connection between the treatment before and during the slaughter and the onset of rigor. An accelerated onset of rigor decreased sometimes the tenderness.

Kastenschmidt and coworkers (1964) showed that both degenerated meat and meat with a high ultimate pH have a rapid onset of rigor mortis. So we can discriminate between a (rapid) alkaline and a (rapid) acid rigor. The ATP breakdown, followed by a complete rigor mortis is probably accelerated by a higher temperature level of the meat. On the other hand we might expect heat development when a lower energy level is reached after completing the rigor state. In other words: a higher temperature promotes a more rapid onset of rigor mortis and this more rapid onset on its turn promotes a higher temperature of the meat

3.4.3. Material and methods

In a total number of 320 pigs, slaughtered in one factory, the temperature, the pH and the rigor was measured 40 minutes post mortem

in the M. semimembranaceus. We used the M. semimembranaceus because this muscle is more suitable for the rigor measuring. Furthermore, this muscle gives a reliable indication about the post mortem processes of the whole carcass. In the M. adductor a fascies often disturbs the rigor measuring. In the presentation we classified the pH and rigor values as follows:

pH classes

1 = $pH_{40} \geq 6.50$
2 = $6.00 \leq pH_{40} < 6.50$
3 = $pH_{40} < 6.00$

rigor classes

I = pre-rigor state
II = onset of rigor state
III = rigor state

3.4.4. Results

The mean temperature of the pH and rigor classes and the distribution of the cases with a high temperature ($\geq 41^{\circ}$ C) are given in table 5 and 6.

Table 5

The distribution over the different pH-classes and rigor-classes of all the cases and those with a high meat temperature ($\geq 41^{\circ}$C)

	pH-classes (pH_{40})			
	$pH \geq 6.50$(1) n ($\geq 41^{\circ}$C)	$6.50 > pH \geq 6.00$(2) n ($\geq 41^{\circ}$ C)	$pH < 6.00$ (3) n ($\geq 41^{\circ}$C)	Total n ($\geq 41^{\circ}$C)
pre-rigor (I)	54 (8)	64 (14)	7 (2)	125 (24)
onset of rigor (II)	13 (4)	62 (19)	13 (11)	88 (34)
complete rigor (III)	13 (9)	55 (34)	39 (33)	107 (76)
Total	80 (21)	181 (67)	59 (46)	320 (134)

Table 6

The mean temperature (with the standard error) in the different pH- and rigor classes

	pH $\geqslant$ 6.50(1)	6.50 $>$ pH $\geqslant$ 6.00(2)	pH $<$ 6.00(3)	Total
pre-rigor (I)	40.3 ± 0.07	40.5 ± 0.07	40.6 ± 0.17	40.4 ± 0.05
onset of rigor (II)	40.5 ± 0.22	40.7 ± 0.08	41.3 ± 0.17	40.8 ± 0.07
complete rigor (III)	41.1 ± 0.22	41.1 ± 0.10	41.7 ± 0.15	41.3 ± 0.08
Total	40.5 ± 0.07	40.8 ± 0.05	41.5 ± 0.12	

3.4.5. Discussion

From these 320 hams 107 (33 %) were already in rigor 40 minutes post mortem and 59 (18 %) had a rapid pH fall.

The tables 5 and 6 give us the impression that a rapid loss of extensibility is related to high temperature but in the pH class 3 the temperature is also pretty high except in I_3.
The combination III_3 gives the highest temperature score.
We may consider class III_1 as the alkaline rigor group whereas class III_3 contains the hams with acid rigor.

We found three times more cases with acid rigor than with alkaline rigor i.e. 39 (12 %) versus 13 (4 %). The mean meat temperature was in both classes higher than the 41° C limit. Within the pH classes we see a shift from pH class 1 to pH class 3 in connection with the rigor development. Of 80 cases in pH class 1, 13 (16 %) were in complete rigor (III) whereas of 59 cases in pH class 3, 39 (66 %) showed the rigor state. Therefore the rapid onset of rigor can be considered as an indication of the rapid post mortem processes in general.
The difference between the distribution of the pH classes over the rigor classes was highly significant (table 7)

Table 7

Distribution of the numbers within the classes

	pH			
Rigor	1	2	3	Total
I	54	64	7	125
II	13	62	13	88
III	13	55	39	107
Total	80	181	59	320

$P < 0.01$

3.4.6. Conclusion

A rapid onset of rigor is accompanied by a high meat temperature. The meat temperature was especially high in the combination with a quick pH fall (III_3).

4.0. Discussion

From the foregoing experiments we got the following picture. The body temperature of the pig has the tendency to rise when the animals are stressed. Animals with a very high meat percentage are more susceptible with regard to a disturbance of the heat regulation which can be explained by the heat development in the course of muscle activity (experiment 3.1.).

When the pigs are slaughtered on a moment when they have a higher body temperature in general the meat temperature is also higher (experiment 3.2.).

In experiment 3.3.1. and 3.3.2. it was shown that environmental factors like transport and pre-slaughter handling in the slaughterhouse had the effect of increasing the meat temperature.

A high temperature was found to be closely related to an accelerated post mortem metabolism in muscle measured by pH-fall and onset of rigor (experiment 3.4.).

This somewhat simplified picture learned us that the pre-slaughter temperature plays a very important role in the development of meat quality aberrations. The rigor measurement 40 minutes post mortem seems to be a good method to get information about the intensity of the treatment before and during slaughter. This is also true for the temperature measurement. The initial pH however gives us no information about the pre-slaughter stress in cases of alkaline rigor.

5.0. Conclusion

A rapid onset of rigor and a quick pH fall has in most of the cases its cause in a high pre-slaughter temperature. These factors are involved in the ultimate meat quality. So the regulation of a too high body temperature is in a lot of cases of great help to reduce the variability of the post mortem muscle metabolism. That can also mean reducing the variability of the meat quality 24 hours after slaughter.

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ZUSAMMENFASSUNG

Der Körpertemperatur des Schweines vor dem Schlachten und deren Einfluss auf die Muskelprozesse nach dem Tode.

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Es wurden Untersuchungen an Schweinen von verschiedenen Rassen durchgeführt.

Die Frage war, ob der Körpertemperatur vor dem Schlachten von wesentlicher Bedeutung ist für die postmortalen Prozesse.

Muskelanstrengungen haben bei fleischreichen Rassen zur Folge, das die Körpertemperatur schneller ansteigt. Es wurde eine Korrelation gefunden zwischen der Körpertemperatur und der Muskeltemperatur 40 Minuten nach dem Schlachten, die variierte von 0.60 bis 0.81 ($P < 0.01$). Transport- und Schlachthofeinflüsse spielen eine wichtige Rolle beim Temperaturanstieg. Weiterhin wurde mit pH- und Rigor mortis Daten gezeigt, dasz die Temperatur meistens zu hoch ist in den Fällen, bei denen eine abweichende Fleischqualität auftritt.

Entweder ist das Fleisch nach 24 Stunden zu dunkel oder es ist zu blass und wässrig.

Gefolgert wird, dasz eine genaue Einhaltung einer normalen Körpertemperatur beim Schwein unmittelbar vor dem Schlachten sehr wichtig ist für das Erziehlen einer gleichmässig guten Fleischqualität. Temperaturmessung kurz vor dem Betäuben der Tiere wäre eine Möglichkeit zum Aussondern der Tiere mit einem erhöhten Risiko für eine schlechtere Fleischqualität.