

CHILLING AND TRANSPORT OF PORK

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SUMMARY

To provide consumers with meat in a good hygienic condition both temperature and distribution time had to be reduced. For prevention of the growth of micro-organisms the surface temperature is far more important than the deep leg temperature. It has been shown in previous investigations that transport of pig carcasses with a low surface temperature, but with an internal temperature above + 7 °C, has no adverse effect on the hygienic condition of the meat. Therefore this kind of transport is allowed in the Netherlands for the home market. The objective of this study was to develop a monitoring system to guarantee that chilling and transport has been carried out correctly. The monitoring system was based on the experience with the transport of partly chilled pork from about 25 slaughterhouses to meat cutting and packaging plants. It appeared that temperature measurements in some well defined sites give a good insight in the performance of the chilling procedure in the slaughterhouse. It is concluded that shipping of meat before the deep leg temperature has reached + 7 °C gives no additional risks for the hygienic condition of the meat. This makes it possible to reduce the distribution time considerably and debone the carcasses at the cutting plant the day after slaughtering. However these results only can be obtained if chilling procedures and chilling equipment of slaughterhouses and refrigerated vehicles fulfil special requirements.

INTRODUCTION

Meat had to be chilled after slaughter to prevent the growth of micro-organisms both in the meat and on the surface of the meat. To achieve a better shelf life the prevention of the growth on the surface is the most important measure. Quick chilling methods give better results than procedures with a moderate chilling rate. Within the European Common Market (EEC) the transport of meat, intended for export to other member countries, is only allowed if the internal temperature of the meat is + 7 °C or lower. There are no EEC regulation with respect to the rate of chilling after slaughter.

Studies in The Netherlands (MOERMAN, 1983 and 1986) had shown that quick chilling of pig carcasses after slaughter, combined with transport before the internal temperature has reached + 7 °C, resulted in meat of good hygienic quality. This quality was comparable with that of meat of carcasses, slaughtered at the same day and transported the next day after complete chilling. A condition for this result was that the cold chain was maintained during the whole process, including loading, transport and unloading. This means that the surface temperature of the meat was kept low continuously. To obtain this result it is necessary that most of the heat of the hot carcass was already removed before loading into the refrigerated vehicles. The chilling capacity of the refrigerated van had to be large enough to remove the remaining heat flow from the carcasses.

Based on these results it is allowed in The Netherlands since 1985, for inland transport only, to carry quick chilled pig carcasses from slaughterhouses to meat cutting plants before the internal temperature has reached + 7 °C. In the regulations based on the Meat Inspection Law detailed requirements are specified with respect to:

- the chilling procedure at the slaughterhouse: at least 70 % of the heat had to be removed before transport;
- the specifications of the refer vans, to guarantee an uninterrupted cold chain;
- the conditions of the loading and unloading areas;
- the chilling capacity of the storage rooms in the cutting plants.

If all these requirements are fulfilled the Meat Inspection Service can give a license for this transport. The experience with these transports and the experiments carried out with respect to these transports are mentioned in this paper.

EXPERIENCES

Since the Dutch regulation, mentioned above, got into force more than 30 slaughterhouses has been checked with respect to the required chilling capacity. Most of them fulfil these requirements and are licensed for this kind of transports. For this reason a calculation method was developed, based on the finite elements method,

for calculation heat transfer in pig carcasses during the chilling process (VERWOERD, 1984). In this way it was possible to calculate temperature profiles in the meat and the enthalpy of the carcasses at any moment of the chilling process.

A typical example of these calculations is given in figure 1. In this case a number of pig carcasses (average weight: 80 kg) was loaded in a chilling room and chilled within 20 hours until a deep leg temperature of $+7^{\circ}\text{C}$ was reached. The required chilling capacity and the temperature of the meat were calculated. These data are compared with measurements in the slaughterhouse. If the measurements are in accordance with the calculated data the slaughterhouse fulfil the requirements and can be licensed.

In the example, shown in figure 1, 70 % of the heat to be extracted was removed in 6 hours. In practice many slaughterhouses use chilling tunnels and temperatures below 0°C . The chilling capacity in these tunnels is much larger than in the example of figure 1. The chilling process in these slaughterhouses goes much faster and 70 % removal was reached within 4 hours. In figure 2a the rate of chilling in 10 slaughterhouses is presented. For comparison also the data of figure 1 are shown, coded with R (reference). The rate of chilling (heat extraction) depends mainly on the chilling capacity of the slaughterhouse and the heat transmission between air and surface of the meat. Chilling rates between slaughterhouses vary considerably. The decrease of the deep leg temperature on the other hand depends mainly on the heat conduction in the meat, which is proportional to the temperature differences between surface and centre. As is shown in figure 2b the decline of the temperature in different slaughterhouses forms a narrow band, the variation is relatively small.

If already 70 % of the heat is removed, transport of the carcasses will have only a minor influence on the rate of decrease of the deep leg temperature. In the last phase of the chilling process (70 to 100 % heat removal) the equilibration of temperature differences in the meat is the limiting factor and not the heat transfer on the surface of the meat.

However it is very important that the surface temperature of the meat will be kept low to prevent a temperature increase and the growth of micro-organisms on the surface of the meat. So it is essential that the chilling capacity of the refer van is large enough to ensure an air temperature of 5°C or lower during the transport. Loading and unloading shall take place in a shielded area to prevent the rise of temperature.

EXPERIMENTS

A number of measurements was carried out in a slaughterhouse to verify the calculations. Special attention was given to the temperature profiles in the meat and the possibility to maintain a low surface temperature during handling and transport.

The following data were measured:

- The deep leg temperature in the centre of the ham. Measurements were carried out during 9 hours.
- The temperature 4 cm under the surface of the ham (rind side). This site reflects very well the rate of chilling, but is not sensitive to short variations of the ambient temperature.
- The surface temperature, measured at the inner side of the rind (about 3 to 5 mm under the surface). This temperature was not measured in the tunnel.
- Air temperature, not measured in the tunnel.

From the calculations the following data are shown:

- Deep leg temperature in the ham.
- Temperature 4 cm under the surface of the ham.

It appeared that it is possible to maintain a low temperature during the transport. However loading and unloading caused a short rise of the ambient temperature. As long as the carcass was not fully chilled there is a temperature difference between air and surface of the meat. This is inevitable since this temperature difference is the driving force for the chilling of the meat. The agreement between the measured and calculated meat temperatures is reasonable. It is likely that the real temperature in the chilling tunnel was lower than the temperature chosen for the calculations. The deep leg temperatures will reach the 7°C level about 14 hours after slaughtering. This is much earlier than in the reference process, mentioned in figure 1.

MONITORING AND INSPECTION METHODS

It has been shown that good results can be obtained with the transport of pig carcasses before the deep leg temperature has reached $+7^{\circ}\text{C}$. If carried out properly no adverse effects with respect to the hygienic condition were observed. These results can only be obtained if the cold chain remains uninterrupted from

slaughtering to deboning (including handling and transport) and the total length of the chilling time, until + 7 °C is reached in the centre, stays within certain limits (preferable not longer than 20 hours). Therefore two conditions had to be fulfilled:

1. A large amount of heat had to be removed in the slaughterhouse before loading into the refer van. In The Netherlands at least 70 % is necessary.
2. During handling, loading, transport, unloading and storage a low ambient temperature (5 °C or lower) is necessary to guarantee continuous chilling until a centre temperature of 7 °C has been reached. This means special requirements for the refer van and the area where the carcasses are handled.

The second condition can easily be monitored by temperature measurements of the air circulating round the meat. A temperature recorder or similar devices may be very helpful.

However the first condition can not be verified without special calculations based on the chilling conditions in the slaughterhouse. If reliable data are not available, verification had to be carried out in an other way. Therefore the following method is proposed.

During the chilling process temperature profiles and gradients are fully dependent on the time/temperature history of the meat. Quick chilling processes cause a steep gradient of the temperature. A slow process a moderate gradient. The latter is also the case if a quick chilling process is not carried out properly. This means that measurement of the temperature profile or gradient can be helpful. This can be carried out by measuring the temperature of the meat at two well defined sites at different depth under the surface of the carcass. These measurements can show if the quick chilling process had been carried out correctly or not. The data mentioned in figure 2 show that after 5 hours chilling (first in a chilling tunnel, followed by further chilling and equilibration in a chilling room) in all cases more than 70 % of the heat was removed. The deep leg temperature at that moment was 26 °C or lower. The temperature at 4 cm under the surface was 19 °C or lower. This means that the temperature gradient between the centre of the carcass and 4 cm beneath the surface of the meat was in all cases about 7 K (7 °C). These two measurements guarantee that the quick chilling process had been carried out correctly. If the quick chilling process was interrupted or had been carried out at a higher temperature than required, the 26 °C-level will be reached at a later moment. At that time more equilibration had taken place and the temperature at a distance of 4 cm under the surface will be higher than 19 °C and the gradient will be less than 7 K.

As can be seen in figure 2 the temperature difference between centre and 4 cm under the surface of the meat decreased from 8 K after 4 hours chilling to 4 K after 8 hours chilling. If the chilling time is unknown the centre temperature can be the base for the gradient:

- centre temperature from 29 °C to 26 °C: gradient: 7 K;
- centre temperature from 25 °C to 23 °C: gradient: 6 K;
- centre temperature from 22 °C to 20 °C: gradient: 5 K;
- centre temperature from 19 °C to 18 °C: gradient: 4 K;

CONCLUSIONS

Transport of meat after slaughtering can be done without adverse effect on the hygienic condition of the meat before the internal temperature has reached 7 °C. However this is only possible if a good chilling process is used and the cold chain is not interrupted during handling and transport. The suitability of the chilling process can easily be checked by measuring the temperature gradient at two well defined sites in the carcass. The cold chain can be monitored by temperature recorders or similar devices.

REFERENCES

- MOERMAN P.C., 1983. The chilling of pig carcasses during transport. 29th European Congress of Meat Research Workers, Salsomaggiore.
- MOERMAN P.C., 1986. Experiences with quick chilling and transport of pig carcasses. In: Recent advances and developments in the refrigeration of meat by chilling. Proc. Meeting IIF/IIR commission C2, Bristol. IIF/IIR, Paris, 1986-3, pp. 499-504.
- VERWOERD M., 1984. Application of a computer program for calculating temperature distribution in perishable products during the cold chain (in Dutch). Koeltechniek 77, 118-121, 142-145.

Figure 1. Characteristic data during the chilling of pig carcasses in 20 hours to an internal temperature of +7 °C.

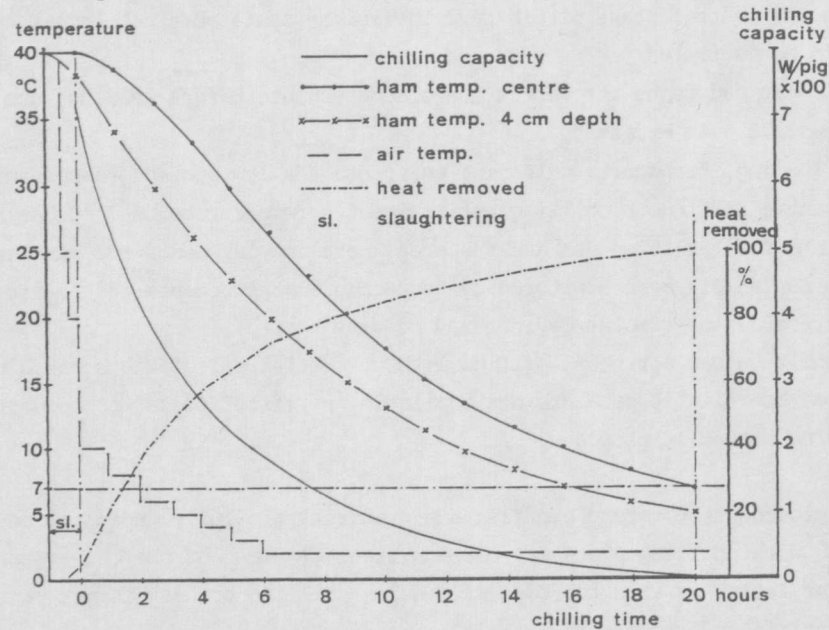


Figure 2. Rate of heat extraction and decrease of meat temperatures during chilling of pig carcasses with a quick chilling proces. Data from 10 slaughterhouses, R = reference methode mentioned in figure 1.

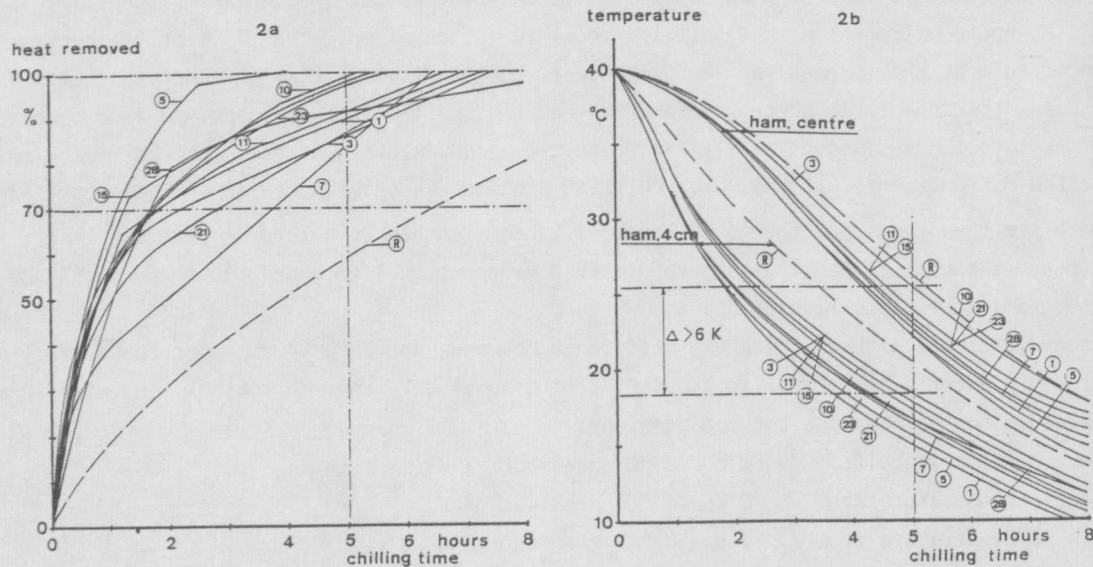


Figure 3. Measurement of temperature of pig carcasses during chilling transport and storage.

