TRANSPORT OF PARTIALLY COOLED CARCASSES

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Abstract – A study was carried out to investigate the possibility to transport carcasses with a core temperature above 7°C without compromising food safety.
A mathematical model, taking into account the geometry of beef, veal or pork carcasses and the cooling processes, was composed to predict the time-temperature profiles after slaughter. The developed model was validated with experimental data from different abattoirs. The validation showed that the model gives an accurate prediction of the time-temperature profile of various carcasses.
A hazard identification and a microbiological risk evaluation based on the time-temperature profiles was performed.
Given that the presence of bacteria is restricted to the surface of carcasses, the transport of carcasses with a surface temperature below 5,5°C and a core temperature below 15°C can be carried out without compromising food safety.
These proposed guidelines could induce a simplification of the logic chain and an energy reduction at abattoirs.

Key Words – Mathematical model, Heat transfer, cooling guidelines

I. INTRODUCTION

The transport of meat within the countries of the European Union is regulated by the regulation EC no 83/32004. According to this regulation, meat can only be transported while having a temperature below 7°C in order to guarantee food safety.
The thermodynamic principles involved in heat transfer give insight in the limitations of meat cooling. Heat can be transferred by convection and conduction. The result of the two processes, i.e. removal of heat from the carcass by convective cooling and heat conduction within the meat, is a relatively quick cooling of the surface of the carcass, and a relatively slower cooling of the inner parts of the carcass as a consequence of the increasingly smaller temperature difference between the inside and the outside.
Given the fact that bacteria are restricted to the surface of a carcass[1], the question was put forward whether a continuous cooling chain (i.e including transport) can be achieved whereby the surface temperature of the carcass always remains below 7°C, in order not to compromise the food safety. If this could be achieved, earlier transport of carcasses could be allowed by the legislator.

II. MATERIALS AND METHODS

Mathematical model

The finite element method (Comsol Multiphysics) was used to develop a model to calculate the time-temperature profile of carcasses after slaughter. The equation used for heat transfer by conduction is described by the formula:

$$\rho \cdot c_p \cdot \frac{\partial T}{\partial t} = \nabla(k\nabla T)$$

in which ρ is the density, c_p is the heat capacity, k is the thermal diffusivity, T is the temperature, and t is the time. The properties of meat are taken from Trujillo and Pham [2].

The equation on convective cooling is described by the formula:

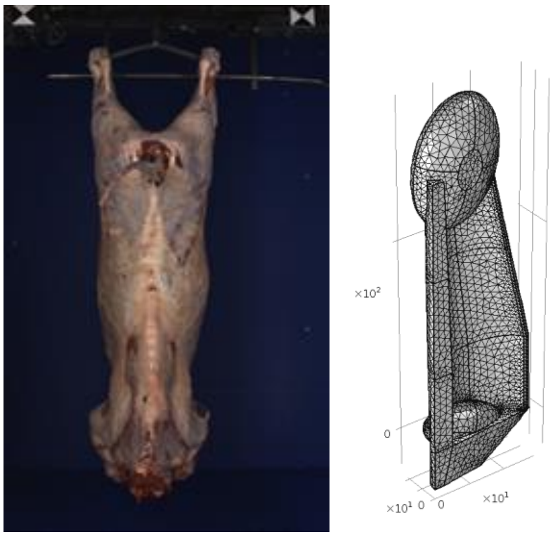
$$q_{Conv} = h_t \cdot (T_{Surface} - T_{Air})$$

in which q_{Conv} is the heat transferred by convection, h_t is the heat transfer coefficient, $T_{Surface}$ is the temperature of the surface of the meat, and T_{Air} is the temperature of the surrounding air.

Geometry

The geometry of the carcasses was derived from literature and from data of different abattoirs (Figure 1).

Figure 1 Photograph of a veal carcass (left) and the geometry of half of a veal carcass used in the mathematical model (right).



Cooling conditions

The heat transfer coefficient and the temperature of the air depends on the different cooling stages in the abattoirs, e.g., spray cooling, active air cooling and passive air cooling (storage). These parameters were derived from practical data from different abattoirs.

Hazard identification and microbiological risk evaluation

Hazard identification was carried out, based on the Scientific Opinion of the EFSA[3,4] and the microbiological risk evaluation was carried out using temperature data from the abattoirs, and the predictive models of Combase [5] and of TNO [6].

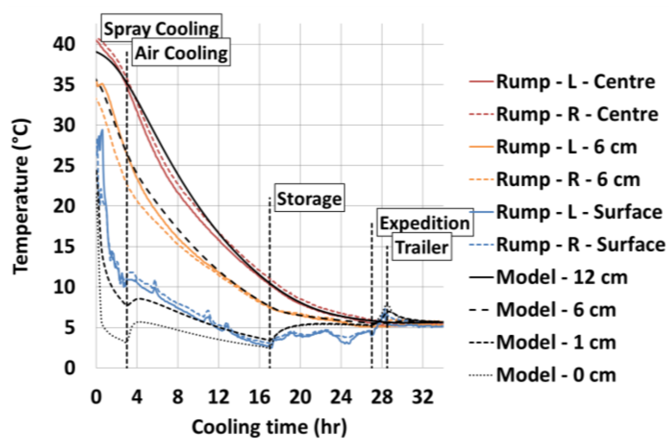
III. RESULTS AND DISCUSSION

Model validation

Validation of the postulated model was carried out by measuring the temperature in veal carcasses with thermocouples connected to (Squirrel) data loggers. The thermocouples were fixed in the rump: in the centre, 6 cm under the surface and directly under the surface.

An example of the model validation is shown in Figure 2. The differences in the first 4 hours of the cooling process between the modelled and measured temperature are related to moisture transport and stress relaxation of the meat fibres, processes which are for simplicity reasons not included in the model. After the first 4 hours, the difference between the modelled temperature and the measured temperature is very small.

Figure 2 Measured and modelled temperatures at different points in a veal carcass of 177,5 kg.



Hazard identification and microbiological risk evaluation

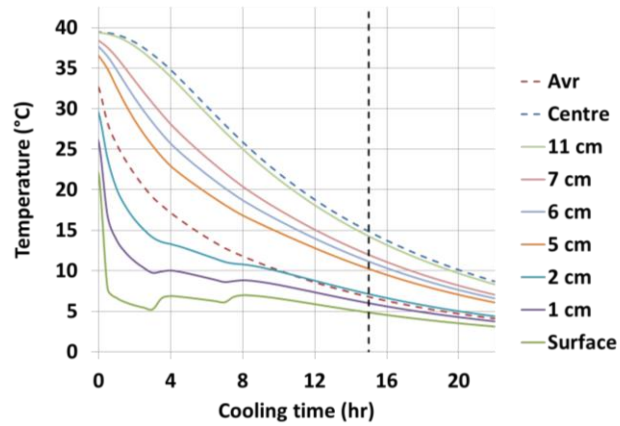
The surface temperature of carcasses has a significant influence on the microbial development and as a consequence on food safety and shelf life. The contamination flora on the surface of carcasses mainly consists of Gram-negative bacteria, such as *Pseudomonas* and Enterobacteriaceae, mostly originating from faecal contamination. At a lower level Grampositive bacteria, such as lactic acid bacteria, *Brochothrix thermosphacta* and *Micrococci*, for instance originating from the hide of the slaughtered animal, will be present. Most of these bacteria are non-pathogenic but might be relevant with respect to spoilage. Taken into account the EFSA priority ranking [3,4] the bacteria *Salmonella* spp., verocytotoxin-producing *E. coli* (VTEC) and *Listeria monocytogenes* are considered in the present risk evaluation. Furthermore the main spoilage organism on carcasses psychrotrophic *Pseudomonas* spp. is considered in the risk evaluation. Limiting conditions of the above mentioned microorganisms are given in Table 1.

Table 1 Limiting conditions for development relevant pathogenic and spoilage bacteria on carcasses.

Bacterium type	**min. a_w**	**min. pH**	**min. T (°C)**	**O_2 req.**
Salmonella spp.	0,94	3,7	5,2	facultative anaerobe
VTEC	0,95	4,0	6,5	facultative anaerobe
Listeria monocytogenes	0,92	4,4	-0,4	facultative anaerobe
Psychrotropic Pseudomonas spp.	0,98	5,5	0,0	aerobe

Both predictive models showed the development of the bacteria at refrigerated temperatures will be relatively slow and the generation times at those temperatures will be more than several hours. This is in line with other research [7,8,9,10] Based on this information and given that the presence of bacteria is restricted to the surface of carcasses, it is concluded that when transport starts at an volumetric average carcass temperature below 7°C and the temperature in the trailer is maintained below 7°C food safety will not be compromised.

Figure 3 Modelled temperatures at different points in the rump of a veal carcass of 180 kg. After approximately 15 hr (dotted line) the volumetric average temperature is 7°C.



Proposed guidelines

The aforementioned data resulted in the following guideline:

For a given carcass, the volumetric average temperature is below 7°C if:

- the surface temperature of the rump is below 5,5°C and,
- the core temperature of the rump is below 15°C.

The required cooling time for a carcass to reach an volumetric average temperature below 7°C depends on the cooling processes at the abattoir. An example is given in Figure 3. At an abattoir approximately 10% energy for cooling can be saved when the transport of carcasses takes place at a volumetric average temperature of 7°C compared to a situation when the transport of carcasses takes place after a core temperature of 7°C is reached (the average temperature of the carcass is 3,5°C).

Demonstration

A model test under practical conditions with veal carcasses was carried out in order to demonstrate the guidelines. To monitor the temperature of the carcasses directly after slaughter, thermocouples were attached in 6 out of 130 carcasses. After the volumetric temperature of 7°C was reached with the cooling system of the abattoir, the carcasses were shipped into a trailer. The carcasses were transported during 10 hours in a cooled trailer (< 4°C). Based on the temperature data retrieved, it is concluded that, as was predicted by the model, the core temperature of the carcasses decreased steadily and the surface temperature never exceeded 7°C.

IV. CONCLUSION

- Given the geometry of beef, veal or pork carcasses and information of the cooling processes, the developed model is able to predict the time-temperature profiles after slaughter.
- A volumetric average temperature of a carcass below 7°C is reached when the surface temperature of the rump is below 5,5°C and the core temperature of the rump is below 15°C.
- Given that the presence of bacteria is restricted to the surface of a carcass, when transport starts at a volumetric average temperature below 7°C and the temperature in the trailer is maintained below 7°C food safety will not be compromised.
- At an abattoir approximately 10% energy for cooling can be saved when the transport of carcasses takes place at a volumetric average temperature of 7°C compared to a situation when the transport of carcasses takes place after a core temperature of 7°C is reached.

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