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Effect of domestic storage and cooking conditions on the risk distribution in ready to cook meat products

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ABSTRACT

The effect of storage and cooking conditions on the safety of meat products has been included in risk assessment simulations. A large number of home devices were measured. Refrigerator temperatures varied from 2 to 12ºC, while ovens showed a variation of ±15 ºC and of ± 10 W/m^2K in heat transfer coefficient at the same nominal temperature. Using a Monte Carlo simulation, the probability distribution of *E. coli* O7:157 was obtained.

Keywords: Keywords: Temperature distribution, Monte Carlo, storage, cooking

INTRODUCTION

Meat products are highly perishable foods which unless correctly stored, processed, packaged and distributed, spoil quickly and may potentially become unsafe due to microbial growth. Systematic management of meat product safety via HACCP includes raw material selection, control of conditions during processing and distribution. The latter is the weaker link of the system. Conditions during transportation and at the retail level are out of manufacturer's direct control and often deviate from specifications. Application of an optimised quality and safety assurance system for the chilled distribution of fresh meat and meat products requires continuous monitoring and control of storage conditions, from production to consumption.

A few investigators have studied storage conditions in commercial and in consumer storage systems. Laguere et al., (2002) reported temperature distributions from 119 refrigerators in France. The authors concluded that 26% of the domestic refrigerators operated at a temperature higher than 8 °C (which is the regulatory requirement for perishable foods in France). In a review of the chilled chain James and Evans, (1992) identify the points of potential hazard. In accordance with the previous researchers, the authors of this study conclude that it is possible that consumers abuse food products. Although there are studies about the storage conditions of perishable foods in domestic and commercial refrigerators, it appears that there is a lack of data about domestic cooking devices.

The objective of this study was to investigate risk of microbial growth due to the uncertainties during storage and cooking of meat products. More specifically within this study we built a database of temperature distributions during storage. Temperature as well convective heat transfer coefficients were obtained for domestic ovens. The measured distributions were used in a Monte-Carlo simulation to obtain the probability distribution of *E.Coli* O7:157.

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MATERIAL AND METHODS

The chilled chain considered is shown in Fig. 1. Prior to distribution centre the products are usually stored under well-controlled conditions (James 1992) and were not considered in this study. In collaboration with local companies temperatures were measured using loggers in 25 retail locations throughout Greece. Although the data obtained up to now, are not enough to obtain statistically significant information about the temperature distribution, it was possible to obtain preliminary data about the storage conditions in retail storage conditions. As the work continues a better approximation of the temperature distribution will be obtained.

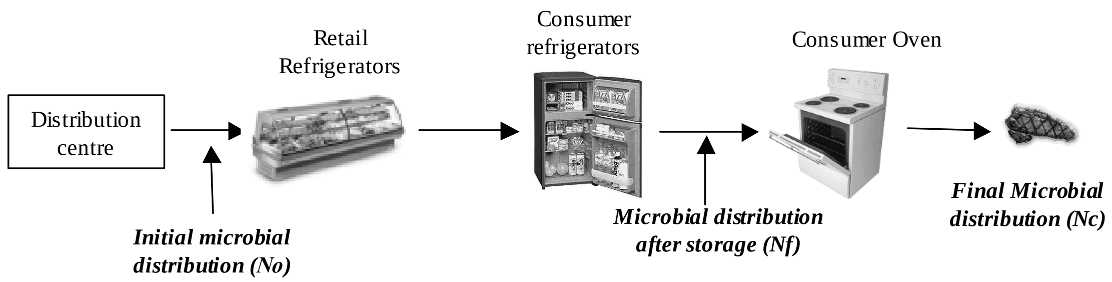

Fig. 1 Chilled chain considered

Temperature distributions were measured in 110 home refrigerators. Computer downloadable, self contained, miniature temperature loggers (Cox Tracer, Belmont, NC, USA) were used to measure temperature in the upper, middle and bottom tray as well as in the door of the refrigerator.

Temperatures were also measured in 40 domestic ovens using a K type thermocouple attached to a temperature logger (Hobo, MA, USA). Another thermocouple was inserted to a stainless steel block having dimensions and shape similar to a piece of meat. Heat transfer coefficient was estimated from the recorder temperatures using the lumped mass approximation.

In order to estimate the temperature history during roasting in more realistic conditions a mathematical model was developed and solved for a burger like geometry. The main assumption in the model was that the moisture diffuses reasonably fast to the surface where it evaporates. A similar model has been developed by Huang and Mittal, (1995). The equations were as follows:

$$\rho C_p \frac{\partial T}{\partial t} = k\nabla^2 T \quad (1)$$

using the boundary conditions:

at the centre $$n \cdot (k \cdot \nabla T) = 0 \quad (2)$$

at the surface $$n \cdot (k \cdot \nabla T) = h(T - T_\infty) - \frac{dM}{dt}\Delta H_{vap} \quad (3)$$

Initially the temperature was considered uniform and equal to 10 °C.

A finite element scheme was used to solve eq. (1). The physical properties of the cooked materials were considered constant with time and were found from Huang and Mittal (1995).

RESULTS AND DISCUSSION

Temperature and heat transfer coefficient distributions
In Fig. 2 temperature variation versus time is shown for a typical retail refrigerator. From Fig. 2 one can see that although variation is quite high, it does not appear that there is any temperature abuse of the food stuff. Although the sample was not large enough to make statistically significant conclusions, from the obtained data it appeared that storage in the studied retail refrigerators did not result in temperature abuse.

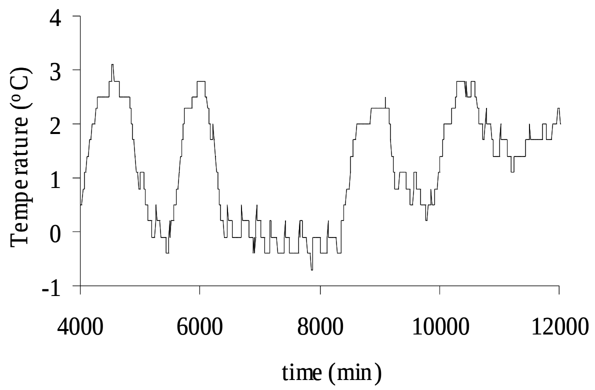

Fig. 2 Temperature distribution in a typical retail refrigerator

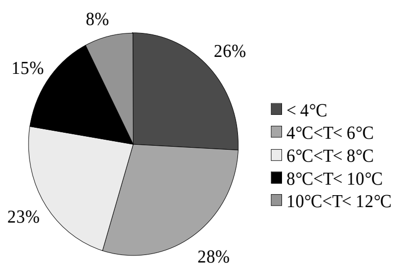

Fig. 3 Distributions of average temperature in domestic refrigerators

In Fig. 3 distribution of average temperature obtained from 110 domestic refrigerators is shown. In few refrigerators temperatures even bellow 0°C was recorded. Opening the refrigerator resulted in sudden temperature rise to 12°C and a subsequent fall to the initial temperature in less than 15 min. Highest temperatures, as it was expected, (typically about 10°C) were recorded in the door of the refrigerator. Although temperature variation with respect to the remaining position was significant, it was not possible to obtain a concise conclusion. In some refrigerators the lower temperature was observed in the middle position, while in others in the upper tray. In all cases though there was a difference of more that 5°C between different positions inside the refrigerator. For the Monte-Carlo simulation an average temperature was used.

In Fig 4. distribution of average temperatures in domestic ovens is shown for a nominal setting of 190 ºC. In Fig. 5 Distributions of heat transfer coefficients are shown for the same ovens. The distribution of heat transfer coefficient appears to be bimodal. This was not to our surprise. Some consumers did not use the fan (or there was not one) resulting in a heat transfer controlled by natural convection. This heat transfer coefficient (approximately equal to 8 W/m^2K) is represented from the smaller peak.

When forced convection was used the mean value of the heat transfer coefficient was 25 W/m^{2}K.

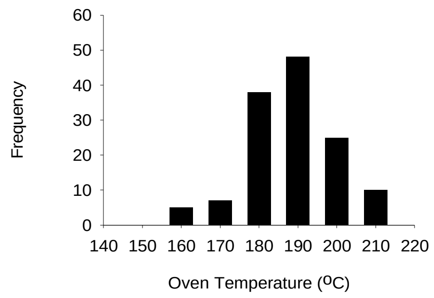

Fig. 4 Distributions of average temperature in domestic ovens

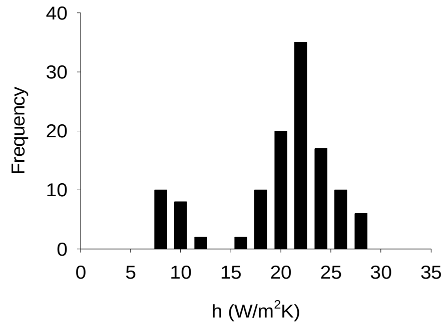

Fig. 5 Distributions of heat transfer in domestic ovens

Finite element Modelling

As it was previously mentioned a finite element model was built in order to predict temperature histories during cooking. The model was evaluated by comparison of temperatures measured in the centre of a burger from the local market with numerical prediction. A number of trials were performed. As one can see from Fig. 6 the model seems to be in good agreement with the experimentally measured temperatures.

A central composite design was used to obtain a relationship of the equivalent processing time, F, for *E. Coli* at 121 ºC with the actual oven temperature and the convective heat transfer coefficient, for 20 min of cooking at a setting of 190ºC. The dependence is shown in Fig. 7. As it was expected higher oven temperatures and heat transfer coefficients result in higher equivalent processing times (F values).

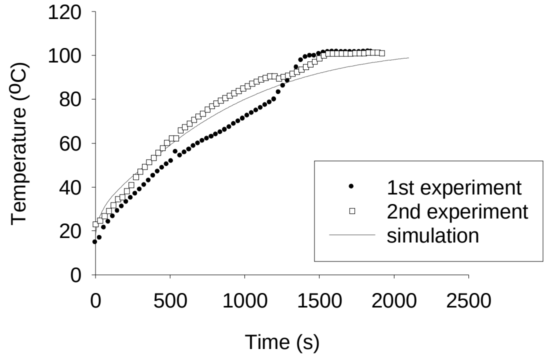

Fig. 6 Comparison of numerically predicted and experimentally measured temperature

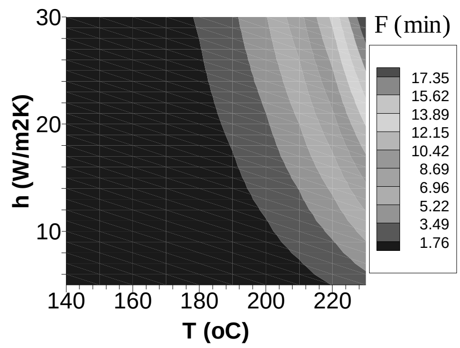

Fig. 7 Effect of oven temperature (Tc) and heat transfer coefficient, (h) on equivalent heating time(F)

Monte Carlo Simulation
In order to account for the uncertainties in the chilled chain a Monte Carlo simulation was used to estimate the probability of *E.Coli* O7:157. Growth and inactivation rates of the microorganism were obtained from ComBase (http://www.combase.cc). A distribution of *E.Coli* O7:157 was assumed in the initial product. Storage of 5 days in retail and domestic refrigerators was considered (Previous data for the retail stage, from Taoukis et al.,1998, was used as relevant data collection is in progress)
In Fig. 8 probability distributions after each step of the chain after 15,000 runs are shown. The number of runs did not appear to have an effect on the resulting distributions. Although cooking resulted in a dramatic reduction of concentration of *E:Coli*, one can see that under some extreme conditions relatively high concentration of *E:Coli* might occur. The occurrence of *E:Coli* in the centre, i.e. in a mass of 25 g, was also estimated. The probability of the centre to have more than 10^3 cfu/g *E:Coli* was about 1%, representing a considerable hazard for the consumer health.

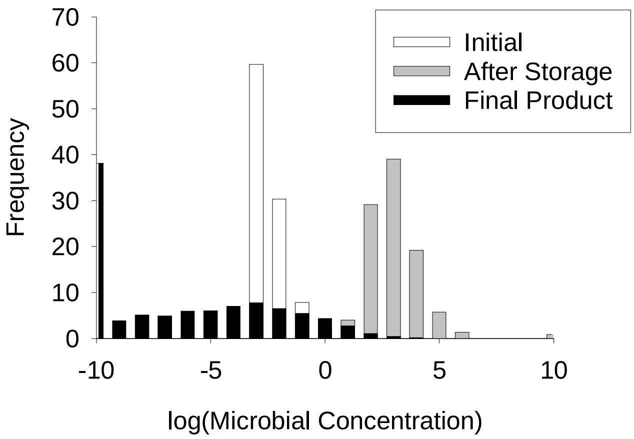

Fig. 8 Microbial Distribution in various steps of the chilled chain

CONCLUSIONS

The chilled chain for meat products was investigated. Temperature distributions were obtained for domestic and retail refrigerators. In retail refrigerators temperature it did not appear to be a temperature abuse of the products. Temperatures in different positions in domestic refrigerators varied more 5ºC. Opening the refrigerator resulted in a sudden increase of the temperature (up to 12ºC). The time needed for the temperature to return to the normal level is approximately 15 min. Measurements in consumer ovens indicated that there is a wide variation of temperature and heat transfer coefficients. A Monte Carlo simulation was used to obtain the probability distribution of *E.Coli* O7:157. The results showed that inappropriate storage and cooking conditions might result in hazard for the consumer health.

ACKNOWLEDGEMENTS

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It does not necessarily reflect the Commission's views and in no way anticipates its future policy in this area.
Information on the project can be found at http://smas.chemeng.ntua.gr

NOMECLATURE

ρ	Density (kg/m^3)
Cp	Specific heat (k/(kg K))
T	Temperature (ºC)
T_∞	Oven temperature (ºC)
T_f	Refrigerator Temperature (ºC)
M	Mass of evaporated water (kg)
k	Thermal conductivity
ΔHvap	Latent heat of vaporisation of water
N	Microbial concentration (gfu/g)

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