Modelling the Effect of House Hold Chilled Storage Conditions on the Risk Distribution of Meat Products

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Abstract

Temperature profiles measured in 250 domestic refrigerators in Greece showed that there is a large variability in the storage conditions of domestic appliances. Almost 10% of the measured temperature distributions had an average temperature greater than 10 ºC. Temperature variation in each profile indicated that estimating microbial and pathogen growth using average temperatures could lead to erroneous results. Temperature profiles were incorporated in Monte Carlo simulations to predict pathogen and spoilage growth during storage. Simulation results showed that there is a probability that meat products could contain levels of food pathogens such as *Listeria monocytogenes* exceeding the relevant safety objectives before they become unacceptably spoiled.

INTRODUCTION

Meat products are perishable and unless processed, packaged, distributed and stored appropriately can spoil in relatively short time. Overgrowth of incidental pathogenic bacteria like *Listeria monocytogenes*, *Salmonella* sp. and *Escherichia coli* may present a potential hazard for the consumer. The chill chain may contribute to excessive microbial growth, with temperature frequently deviating from specifications. Few investigators have studied storage conditions in commercial and in consumer storage systems. In a review of the chilled chain James and Evans, (1992) concluded that it is possible that abuse food products can occur during storage in domestic refrigerators. Laguere et al., (2002) reported temperature distributions from 119 refrigerators in France. Within the refrigerators temperature variations were attributed to temperature regulation from the thermostat. Furthermore, temperatures profiles measured at different locations, in the same type of refrigerator, varied significantly. However when data were analyzed for all types of refrigerators the differences between temperature profiles obtained at different locations were not significant. No relationship was found between the temperature measured using a thermometer and a data logger over a 7-day period. This implies that temperature measured using a thermometer does not represent the true operating conditions of the refrigerator. The authors concluded that 26% of the domestic refrigerators operated at a temperature higher than 8 ºC. Sergelidis et al., 1997 investigated temperature distributions in 136 domestic and 228 commercial refrigerators. Although, temperature distributions are not reported, the authors concluded that 50% of the domestic and 32% of the commercial refrigerators had temperatures greater or equal to 9 ºC.

Usually spoilage and risk are considered as separate problems and most calculations take into account one or the other for making decisions on shelf life or safety risk of studied products. However since these are parallel events and given the fact that a spoiled product is not likely to be consumed the realistic risk refers to products that are still acceptable quality wise (i.e. bellow spoilage level) but have pathogen loads exceeding the respective safety objectives. The goal therefore is to estimate the relative percentage of products that could pose a potential risk, i.e.

exceed the safety objective, prior to spoilage versus products that spoil before safety would become an issue under realistic domestic storage conditions.

MATERIALS AND METHODS

Temperature distributions were measured in 250 refrigerators of Greek households under domestic use. Consumers reperesented all economic, social backgrounds and ages in the Athens metropolitan area. Self contained, computer downloadable miniature temperatures loggers (Cox Tracer, Belmont, NC, USA) were used to measure temperature in the various locations to account for differences within the refrigerator.Programs to post process temperature distributions were developed in Matlab environment. The software was designed to filter temperature distributions estimate average values and standard deviation for each temperature profile. Standard deviation was used as a measure of variability and was estimated for all period of storage (7 days).

Monte Carlo simulation was used to predict the distribution of pathogen and spoilage growth using the experimentally measured temperature profiles. In each Monte Carlo case an experimentally measured temperature profile was randomly selected and used to estimate microbial growth under dynamic temperature conditions. This Monte Carlo simulation accounts for uncertainty in storage conditions. The same computational process was used repeatedly with different initial pathogen and spoilage load combinations in order to investigate the effect of the variability of the initial load.

RESULTS AND DISCUSSION

Temperature profiles in domestic refrigerators are indispensable when trying to evaluate pathogen and spoilage growth during storage.

In Fig. 1 a typical temperature profile is shown. In this profile although average temperature is acceptable (5.7 ºC), for approximately 5 % of the storage time temperature exceeds 10 ºC.

Statistical analysis of the temperature profiles led to interesting observations. In Fig. 2 the probability distribution of the average temperatures, Tav, obtained from 350 profiles is shown. A significant spread in the average temperature was observed. While the mean of Tav was 6.3 ºC, for almost 10% of the locations in home refrigerators Tav was greater than 10 ºC, while temperatures as low as -2 ºC were measured. The distribution of average temperatures was adequately fitted by a normal distribution (shown in Fig. 2 with the solid line) having mean of 6.3 ºC and standard deviation of 2.7 ºC. The value of standard deviation quantifies the variability that exists among different domestic appliances, which should be taken in consideration when assessing risk associated with storage.

As one can see from Fig. 1 there is a significant variation within each temperature profile. In order to evaluate the variability within each profile, in addition to the average temperature the standard deviation was also estimated. In Fig. 3 the distribution of standard deviations for the 350 measured temperature profiles is shown. From Fig. 3 one can see that using only a single average temperature to describe storage in a domestic refrigerator can be inaccurate since quite often the variability can exceed 1.5 ºC.

It should be stressed that most risk assessment studies use only the average temperature to characterize storage conditions in domestic appliances. In the case of a pathogen that grows only at temperatures greater than a minimum temperature zone the representation of the temperature profile shown in Fig 1 by a single temperature could lead to erroneous results. In this study all the experimentally obtained temperature profiles and not the average temperatures were used to predict the risk distribution of fresh meat products. Risk is a probabilistic event, therefore, risk estimation has to take into account the distribution of storage conditions and the probability of initial loads of spoilage and pathogen bacteria. Spoilage and pathogen level are often independent of each other therefore various combinations of initial loads for pathogens (e.g *Listeria monocytogenes*) and spoilage bacteria (e.g. pseudomonads) were investigated. Kinetic parameters used in the calculations reported below were as follows: $\mu_{ref} = 0.066\ h^{-1}$(exponential

growth rate at reference T=10° C), and Ea = 95 kJ/mol (Activation energy of Arrhenius plot) for *L. monocytogenes* and μ_{ref} = 0.048 h^{-1} (at T_{ref}=0° C), and Ea = 70.1 kJ/mol for pseudomonads growth on ground pork (Koutsoumanis, unpublished data, EC RTD project SMAS, QLK1-CT2002-02545). *Listeria monocytogenes* and pseudomonads growth was calculated throughout the obtained temperature range.

In Fig. 4 probability distributions for level of growth after 5 days of domestic storage for initial loads of *L. monocytogenes* and pseudomonads of 10^0 cells/g and 10^2 cells /g are shown. In this case it was calculated that most products will be rejected due to excessive growth of spoilage bacteria (>10^8/g) before *L. monocytogenes* reaching a set level of risk. The upper risk level for a pathogen depends on the "safety objective" that can be quantitatively translated in an acceptably low probability of illness. In the case of *L. monocytogenes* one can use as a conservative limit the 10^2 cells /g that is proposed for ready to eat meat products. In Fig. 5 the distribution of corresponding "pairs" of spoilage and pathogen numbers after the 5 days of domestic storage is shown. For levels of pseudomonads less than the 10^{10} cells /g of the stationary phase, a near linear relationship appeared to exist between the levels of *L. monocytogenes* and pseudomonads. This is expected since for both *L. monocytogenes* and pseudomonads the temperature depended exponential growth was calculated, at the same temperature profiles. For this case it was calculated that 3% of the products may surpass the limit of *L. monocytogenes* (10^2cells/g) before being spoiled (i.e. pseudomonads <10^8cells/g).

Typically a distribution of initial load exists in meat products. Thus, in order to investigate the effect of the variability of the initial load the logarithm of the initial load was simulated using a normal distribution having means of 0 and 2.65 log cells/g and standard deviation of 0.5 for *L. monocytogenes* and pseudomonas respectively. Based on a Monte Carlo simulation (2000 runs) corresponding "pairs" of spoilage and pathogen numbers after 5 days of domestic storage respectively were estimated (Fig. 6). Introduction of a distribution rather than a single value for the initial load, resulted in a greater variability of the *L. monocytogenes* and pseudomonas load after storage. A 15% probability for the product to become "unsafe" i.e. pathogens to exceed the level of 100 cell/g, while still being acceptably "unspoiled" (pseudomonads <10^8 /g) was calculated. A 39% of the products would have reached "unsafe" level after being rejected as spoiled.

Simulations (over 50000 Monte Carlo runs) were performed for various combinations of initial pathogen-spoilage load in order to investigate its effect. The value of interest was the ratio of 'unsafe' products, i.e. products that exceed the safety objective for *L. monocytogenes* (<10^2cells/g) while levels of pseudomonads remain at acceptable levels (<10^8cells/g), after five days of storage. In each simulation run one pair of initial load at a randomly chosen temperature profile was used. In Fig 7 a contour plot showing the effect of initial load to the ratio of the 'unsafe' products that are still below spoilage level. As it was expected increasing the initial load of pathogens resulted in an increase of the ratio of 'unsafe' products.

CONCLUSIONS

Temperature distributions were measured in various locations in 250 refrigerators in Greece resulting in a total of 350 temperatures profiles. Variation of temperatures in each profile indicated that when estimating pathogen growth using the profile rather than the average temperature is more appropriate. Overall, based on a large number of calculations with different combinations of initial loads it was shown that only in cases where a very low initial spoilage load combined with significant incidental pathogen contamination occurs there is measurable probability that products will potentially violate the safety objective before they become unacceptably spoiled.

ACKNOWLEDGEMENT

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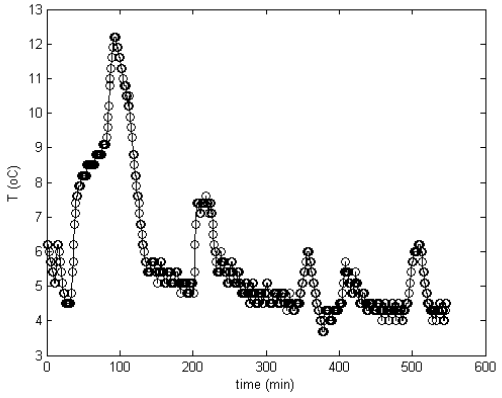

Fig 1 Temperature variation in a domestic refrigerator

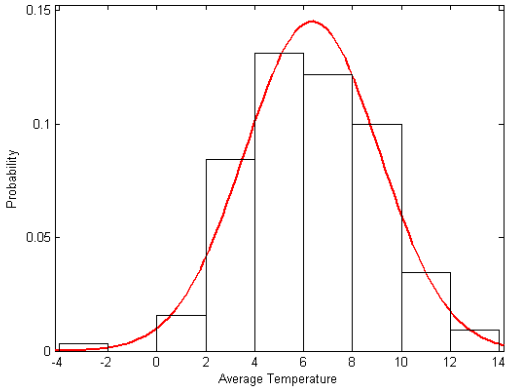

Fig 2 Probability Distribution of average temperature in domestic refrigerators

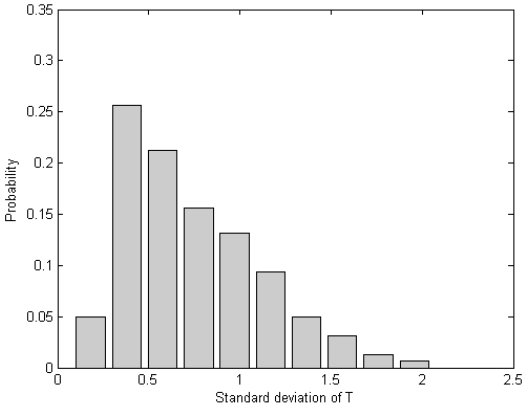

Fig 3 Probability Distribution of standard deviation in temperature profiles in domestic refrigerators

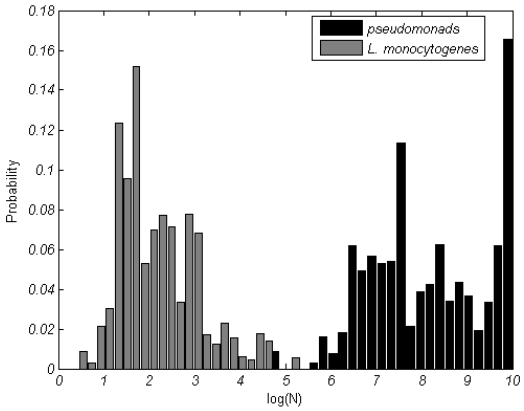

Fig 4. Probability distribution for level of growth of *L. monocytogenes* and pseudomonads after 5 days of storage in domestic refrigerators. Initial load for *L. monocytogenes* and pseudomonads were 10^0 and 10^2 respectively

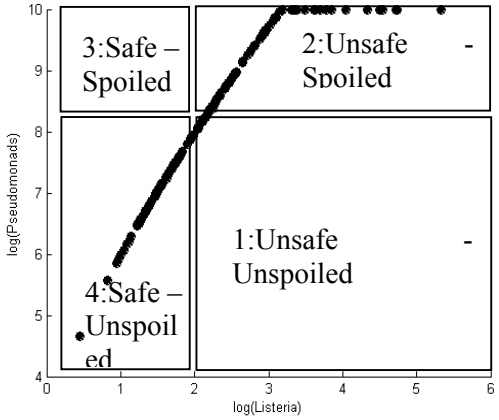

Fig 5. Distribution of corresponding "pairs" of spoilage and pathogen numbers after 5 days of storage in domestic refrigerators. Initial load for *L. monocytogenes* and pseudomonads were 10^0 and 10^2 respectively

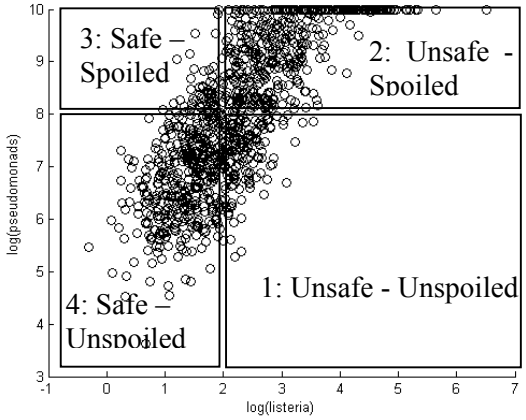

Fig 6. Distribution of corresponding "pairs" of spoilage and pathogen numbers after 5 days of storage in domestic refrigerators. Initial load for *L. monocytogenes* and pseudomonads was a lognormal distribution with means of 0 and 2.65 respectively. The percent of products in box 1 (Unsafe – Unspoiled) is 15%, in box 2 is 39%, in box 3 is 6% and in box 4 is 40%.

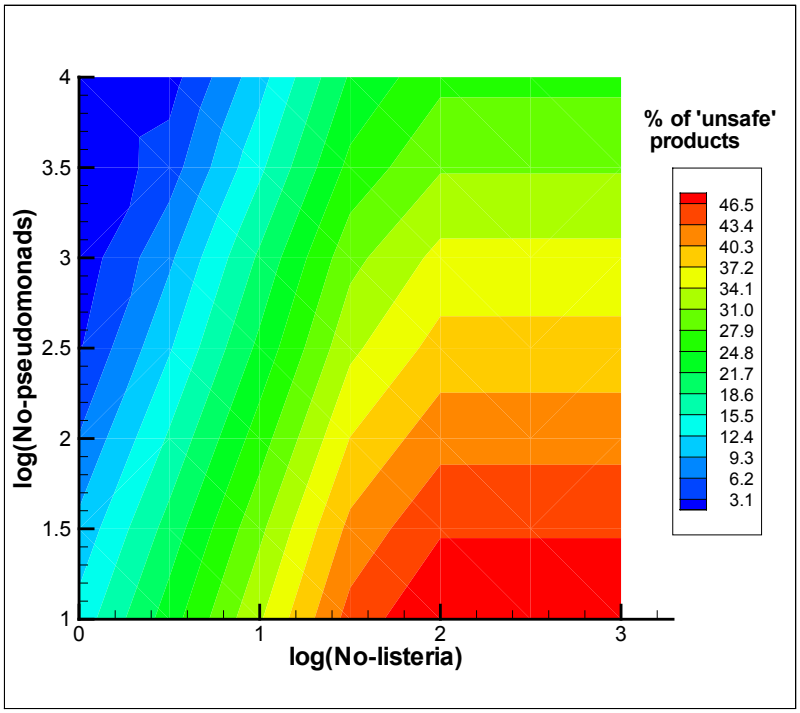

Fig 7. Contour plot showing the effect of initial pathogen and spoilage load on the % of "unsafe-unspoiled" meat products after 5 days of domestic storage.