Abstract

A stochastic risk assessment model aiming to evaluate the risk for human health posed by Salmonella spp., associated to the consumption of fresh pork sausages in Ireland, is under development. The variability in the initial level of Salmonella in raw pork sausages (Y0) at retail was derived from MPN data, modelled as a log-normal distribution (E(Y0)=1.80 log CFU/g; 95% CI: 1.17-2.30 log CFU/g) using Irish survey's data. The Baranyi's primary growth model and the square secondary model were applied to simulated temperature profiles to predict the Salmonella levels after transport and refrigeration (Y(t)). While the Salmonella levels of fresh pork sausages prior to cooking did not increase significantly during transport and home storage (E(Y(t))=1.85 log CFU/g; 95% CI: 1.25-2.76 log CFU/g), the probability of finding hazardous Salmonella levels above 4 log CFU/g from contaminated sausage packs was 0.36% (95% CI: 0.09-0.92%). Sensitivity analysis showed that the Salmonella levels in raw sausages are more affected by storage time (R=0.43) than by average temperature (R=0.17).

Introduction

In Ireland, a pork product likely to be associated with food-borne salmonellosis is the fresh pork sausage for being a raw comminuted product that is widely consumed – according to the Irish consumer's database, 55 g of sausage per week is consumed on average per person. Assuming that approximately 65% of the population consume pork sausages, an average of 7800 metric tons would be consumed each year. Thus, the objective of our research was to develop a stochastic risk assessment model in four modules for estimating the risk of salmonellosis from consumption of Irish-style fresh pork sausages. The methodology and results of the first two modules – transport and home refrigeration – will be presented here.

Methodology

The initial concentration of Salmonella in fresh pork sausages from contaminated packs produced in Ireland was approached using the MPN data compiled in Mattick et al. (2002). Distributions for the transport time (t̄), refrigeration time (tb) and average fridge air temperature (Tavg) were fitted to Irish data from Kennedy et al. (2005).

The growth of Salmonella spp. (Y(t)) during transport and refrigeration was evaluated from t̄ (time of purchase) using the dynamic Baranyi's growth model (Eq. 1). The growth was calculated in small time intervals using temperature profiles (T(t)) that were modeled as a continuum for transport and home refrigeration (Figure 1). The estimates of Salmonella growth rate (µmax) in fresh bratwurst obtained from Ingham et al. (2009) were used as surrogate data, and further expressed as a function of temperature using the square-root secondary model (p<0.01, R²=0.77), where T is the product's temperature (°C), b is a constant (1/°h°C) and Tmin (°C) is the nominal minimum temperature for Salmonella (Eq. 2). Normal distributions for b and Tmin as well as for Q0 (Baranyi's lag-phase parameter also derived from Ingham et al. (2009)) were assumed to describe the variability in Salmonella growth rate.

For the entire duration of transport t̄, the temperature profile (T(t)) of the centre of a sausage pack of half dimensions was modeled using one-dimensional transient heat transfer equations. The initial temperature T0 corresponded to the sausage temperature at retail.

For the refrigeration module, experiments were conducted to capture the oscillations in the temperature of a sausage pack stored in domestic refrigerators up to 7 days. Mimicking the experimental data, T(t) for the refrigeration module was modeled in two stages: a brief temperature adjustment stage (~2-3 h) governed by heat transfer equations until approaching Tsuper and a temperature oscillation period, which consisted of a temperature history section (t, Tavg) randomly sampled from the above experiment within the corresponding category until the completion of the total refrigeration time (tb). For the temperature adjustment stage, the overall convective heat transfer coefficient (h) of the cold air to the surface of the product was estimated from the temperature data and assumed to be constant for all the surfaces of the product. For the three-dimensional system, T(t) was modeled using a product's initial temperature at T0 (product's temperature at the end of transport) and Tb = Tavg.

The simulation model was written in Matlab 7.0 (The Mathworks, Inc) and run for 10000 iterations.

Results

While on average the Salmonella concentration did not increase significantly after transport and home storage (E(Y0) = 1.85 log CFU/g) because in most cases the Salmonella cells remained in the lag phase, the frequency distribution of Salmonella levels after refrigeration presented a longer right tail (95% CI: 1.25-2.76 log CFU/g). This occurred due to the possibility of temperature abuse during home storage, as illustrated in Figure 1, where the sausage pack subjected to a simulated temperature of −11°C presented exponential growth around 20 hours after purchase. When the model was run separating uncertainty from variability, the probability of finding hazardous Salmonella concentration above 4 log CFU/g (that may not be inactivated sufficiently by cooking) from a contaminated sausage pack was estimated at 0.36%, with a 95% CI of 0.05-0.92% (Figure 2). Sensitivity analysis has shown that the Salmonella level in fresh sausages prior to cooking is highly influenced by the initial Salmonella load (R=0.77), and is more affected by storage time (R=0.43) than by the average fridge temperature and its oscillations (R=0.17). Figure 2 suggests that approximately beyond 2 days of storage, hazardous Salmonella concentrations are more likely to occur.

Conclusions

Microbial growth has been estimated for changing temperatures and incorporated into the risk assessment model. The concentration of Salmonella in fresh pork sausages from a contaminated pack prior to cooking was estimated to be within a 95% CI of 1.25-2.76 log CFU/g, although ~0.36% of the times, hazardous levels that may not be sufficiently inactivated by cooking can be present.

References


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