RESEARCH ABSTRACT

PORK SAFETY

Title: Quantifying the Effect of Slow-Cooking Operations on the Thermal Resistance of *Salmonella* in Whole-Muscle Pork Products - **NPB #09-065**

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Scientific Abstract

The *overall goal of this project* was to improve the reliability of thermal process validation tools for *Salmonella* in pork products, by accounting for stress adaptation that can occur during slow cooking processes. The *specific objectives* were: (1) To modify, for ground and whole-muscle pork products, a model recently developed at MSU to predict the rate of *Salmonella* thermal inactivation as a function of both product temperature *and* prior (sub-lethal) thermal history, and (2) To validate this model via pilot-scale challenge studies using ground and whole-muscle pork products inoculated with *Salmonella*.

Salmonella-inoculated pork products were heated in four different heating/cooking systems at three different scales. Small samples (1 g) were heated in a thermocycler to generate a set of well-controlled temperature profiles and thereby generate inactivation data that were used to estimate parameters of a modified thermal inactivation model accounting for sublethal history and its effect on subsequent thermal resistance of *Salmonella*. Traditional inactivation models (D and z) and the modified model were applied to validation data generated by cooking inoculated pork patties and whole-muscle products in a custom, bench-scale, moist-air convection oven, a pilot-scale impingement oven, and a pilot-scale, moist-air convection oven (using cooking processes that mimicked commercial operations). Surviving *Salmonella* were enumerated, and experimental process lethalities (log reductions) were compared to those calculated using the collected core temperature data and the inactivation models.

The laboratory-scale studies demonstrated that the traditional, log-linear inactivation models can over-predict *Salmonella* lethality ($P<0.001$) when applied to processes that subject the product to significant time in the critical sublethal temperature region (i.e., 40-50°C or 104-122°F). A modified inactivation model, in which the thermal inactivation rate is a function of current temperature *and* an integral of the prior sublethal history, eliminated this systematic over-prediction of lethality, reducing the root mean squared error (RMSE) by 82% and reducing the over-prediction bias from 2.6 log to an under-prediction (fail-safe) bias of 0.3 log.

Bench-scale oven treatments (20 g pork patties and mini-steaks, 1 cm thick) validated the above findings. For both the ground-and-formed and whole-muscle pork products, the traditional inactivation model (D and z values from prior isothermal laboratory studies) significantly ($P<0.001$) over-predicted lethality, with individual errors as large as 2.1 and 6.0 log, respectively. For the pork patties, the size of the computed lethality error increased ($P<0.01$) with increasing sublethal history (corresponding to cooking times up to 115 min).

At the pilot-scale, impingement cooking of pork patties and whole-muscle pork chops was used to test the utility and validity of D and z values previously determined in isothermal laboratory studies with both product types. For the whole-muscle product, the RMSE and bias were 1.5 and 0.8 log, respectively. For the patties, these values were larger (2.4 and 1.1), but 88% of the pilot-scale outcomes fell within the 95% prediction intervals for computed lethality. These outcomes are consistent with expectations, given that the fast cooking times in this system (< 9 min) did not cause any significant sublethal heating.

In pilot-scale, slow cooking trials (86-253 min) with inoculated (6.3 log CFU/g) whole-muscle pork roasts, processing to endpoint temperatures ≥71.1°C (≥160°F) resulted in no countable surviving *Salmonella*. Although sublethal injury causes increased thermal resistance, slow cooking to this endpoint yielded sufficient cumulative lethality to overcome this effect. Nevertheless, scale-up to the pilot-scale caused significant increases in the inherent uncertainty associated with the application of lethality models (0.08 to 1.5 log), and commercial processors should account for this factor when validating the safety of cooking operations.