Use of the AMI Process Lethality Spreadsheet to Validate the Safety of Cooking Procedures

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Introduction

Producers of cooked meat and poultry products are increasingly being required to produce documented, science-based validations of thermal processes. Traditional thermal death-time studies require relatively extensive laboratory facilities, time and expertise. When D and z-values are known (through experimentation or by obtaining published values), there remains the question of how to apply these variables to an actual thermal process. The American Meat Institute Foundation (AMIF) has sponsored the development of a process lethality spreadsheet that can be used to estimate the effectiveness of specific heat processes in destroying microorganisms of concern. This model is readily available for downloading from the AMIF's web site. With the input of the proper variables, this spreadsheet can quickly indicate the total kill potential of a specific cooking process for any of the common food-borne pathogens of concern. This presentation will provide a practical introduction to the use of this model and will discuss the appropriate use of the data that is generated.

Integrated time-temperature processing has been used in the canning industry since about 1920, so the concept is not new. This model fits very well into our modern concept of Hazard Analysis and Critical Control Points (HACCP). The integrated model involves two very different sciences: the biology of microbial heat destruction and the physics of heat transfer into products. In simple terms, integrated time-temperature processing is a consideration of all of the heat that is applied during a thermal process, including the heating time (or come-up time), the holding time, and the cooling time. Because most vegetative pathogens that are of concern to our industry begin to die at temperatures as low as 110°F, we can achieve significant microbial reductions during the heating and cooling times surrounding our minimum internal target temperature.

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Thermal Destruction of Microorganisms

Many factors affect the heat resistance of microorganisms. First, different types of bacteria vary widely in their sensitivity to heat. Spore-forming bacteria such as *Clostridium botulinum* can survive several minutes even at autoclave or retort temperatures and pressures. Vegetative bacteria are much less resistant to heat. Within the vegetative bacteria, gram-positive bacteria such as *Listeria monocytogenes* are generally more heat-resistant than gram-negative's like *Salmonella.* There can even be significant differences between species within the same genera and strains within the same species. Another factor that can affect heat resistance is the physiological state of the inoculum. The age of the culture and the conditions under which it was grown can have a large effect. For example, many studies have shown that sub-lethal heat shock can induce increased heat resistance. The matrix within which the organisms are heated can also greatly influence heat resistance. Water activity is one of the most important factors. Wet heat is much more effective at killing microorganisms than dry heat. For example, it would take a much more intense heating process to destroy bacteria in cooked bacon or beef jerky than it would in raw ground beef. The percentages of fat, salts, carbohydrates, pH, proteins and other substances also affect thermal destruction of microorganisms. When thermal death-time studies are conducted in the laboratory, the type of growth medium used to recover the heated cells can also be critical. Selective media will generally recover significantly fewer injured cells than will non-selective media. Reduction of the oxidation-reduction potential of the medium or addition of reducing agents or sodium pyruvate will also enhance recovery of injured cells.

In the laboratory, we can take all of the above variables into consideration and conduct a thermal death-time study. A specific organism is chosen and placed into a specific matrix (broth, food emulsion, etc.). Several methods are used, but typically the inoculated matrix is sealed in a capillary tube or plastic pouch. It is then heated to a specific temperature, held for a defined period of time, rapidly cooled, then surviving cells enumerated. This sounds simple, but in reality these studies can be difficult to perform and should be done in a competent and experienced lab. When samples have been treated for a range of times, the data can be plotted and a decimal reduction value (D-value) can be obtained. The D-value is the time (in minutes) at a specific temperature that is required to kill 90 % of the target microorganism, or in other words, the

time at a specific temperature that is necessary to achieve a one-log reduction. If we repeat these studies at several different temperatures, we can calculate a z-value. The z-value is the number of degrees necessary to change the D-value by a factor of ten. Again, D-values and z-values correspond to a specific microorganism in a specific matrix. An excellent resource that summarizes published D and z-values is the ICMSF Book 5 (ICMSF, 1996). Another term that must be defined for the purposes of the integrated time-temperature model is the F-value. In traditional canning terms, this is the equivalent time, in minutes, at 250°F of all heat considered, with respect to its capacity to destroy spores or vegetative cells of a specific organism. When used in the context of the AMI model, the F-value is the cumulative process lethality, or the equivalent amount of time at the reference temperature.

Product Heating

Consideration of the heat penetration into the product also involves many variables. If microorganisms are potentially spread throughout the product, as in emulsified products, the coldest spot within the product must be considered. In most products, this is the geometric center of the product. Many devices are available to track internal temperatures. Electronic thermocouple probes that sense heat only at the tip of the probe are recommended. Bimetallic (dial) thermometers sense the average temperature over the length of the stem, and do not provide an accurate indication of internal temperatures (Snyder, 1999). Obviously, small products, such as bacon slices, heat and cool very fast, and obtaining accurate internal temperatures can be very problematic. Large products such as deli turkey breasts will have much longer heating and cooling times and so will be more significantly influenced by the integrated time-temperature model. Other variables to be considered when doing a heat penetration study include weight, shape, fat content, moisture, density, initial temperature and packaging material. In studies that we conducted, we found a significant difference in heat transfer between products coated with cracked pepper then sealed in a cook-in-bag package versus product with no cracked pepper. The pepper caused tiny insulating air pockets to form between the packaging material and the product.

In addition to the variables caused by the product, the actual heat process used will affect heat penetration. Steam impingement ovens, hot air ovens, water baths and microwave ovens are examples of very different heating processes.

AMI Integrated Time-Temperature Process Spreadsheet

Current USDA regulations allow the development of thermal processes based on decimal reductions of pathogens of concern (performance standards) rather than prescribing specific time-temperature heating regimens. An excellent tool that can be used to help satisfy these requirements can be found at www.amif.org. This "Process Lethality Determination Spreadsheet" was developed by Larry Borchert with support from the American Meat Institute Foundation.

To use the spreadsheet, one must obtain a z-value for the specific product in question. A list of z-values for several organisms of interest is included as a table within the spreadsheet. However, a literature review should be conducted to find the most appropriate values for your product. If a log reduction value is desired, a D-value at a specific temperature must also be acquired. If a review of the literature indicates that a thermal death-time study for the organism in question has not been conducted in a very similar product, a complete thermal death-time study may need to be conducted. In addition to acquiring z and D-values, a heating study must be conducted in the target product, so times and temperatures can be inputted into the spreadsheet.

When a z-value, times and temperatures have been entered into the spreadsheet, and F-value will be computed, and data will be plotted on two graphs. The F-value will automatically add itself up in the third column. The highest F-value represents the process lethality, which is the number of minutes that would be equivalent to holding the product at the single reference temperature. Using the data that is included in the initial spreadsheet, the maximum F-value is 760.25. This means that the total heat process, including the heat-up and cool-down times is equivalent to holding the product for 760.25 minutes at the reference temperature of 145°F. If we divide this number by the D-value, we can calculate the log kill. For example, for *Salmonella* the process would provide a 1086 log kill. Note that it is not unusual to obtain very large kill values. Most processors will find, especially with large products, that they are applying a very conservative heat treatment based on reaching a minimum internal cook temperature.

Benefits and Cautions

The integrated time-temperature processing spreadsheet can be used to develop custom heating regimens. If all variables are controlled, it can be used to develop critical control points and monitor processes based on process parameters such as oven temperature and belt speed rather than relying on probing product to monitor minimum internal cook temperatures. This can reduce the need to puncture cook-in-bag products, and optimize heating processes to reduce energy costs and increase yields and product quality. However, the data obtained by the use of this model is only as accurate as the information that is put into it. As with most models, it should be used to get into a ballpark range, then further studies such as laboratory challenge studies should be conducted to completely validate the process.

References

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