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O'Brien, G.D. (1997). Domestic refrigerator air temperatures and the public's awareness of refrigerator use. International Journal of Environmental Health Research, 7, 141 - 148.

Princop, E., Tofan I. (2009). Considerations about consumer's attitude regarding the significance of cold chain of perishable dairy products. Annals. Food Science and Technology, 10, 478-481.

Terpstra, M.J., Steenbekkers, L.P.A., de Maertelaere, N.C.M. & Nijhuis, S. (2005). Food storage and disposal: consumer practices and knowledge. British Food Journal, 107, 526-533.

Tom, P. D. (2006). Managing the cold chain for quality and safety. Available online: URL: http://seafood.ucdavis.edu/pubs/coldchain.doc, 28.07.2010.

Zander, U.: "MAHL-ZEIT?" Ernährungsalltag vom Familienhaushalten. In: Baier, E.: Verpflegung im Wandel - Herausforderungen für Geräte, Verfahren und Lebensmittel. Jahrestagung des Fachausschusses Haushaltstechnik der Deutschen Gesellschaft für Hauswirtschaft 2005. Aachen: Shaker, 2005.

Conceptual Models for Safe Heating and Cooling in the Catering Supply Chains

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Keywords: heat treatment, cooling profile, safety, performance criterion, process criterion

Abstract

According to the Danish catering industry, it is a challenge to keep a high culinary quality of certain foods because of the official requirements for safe holding either at hot or chilled temperatures. For heating, a temperature of at least 75°C is recommended if the company cannot document product safety by other means. Equivalently for safe cooling, it is recommended to cool down from 65°C to 10°C in max. 3 h. In both cases, EU legislation gives the possibility to apply other time and temperature combinations as long as the company can document that the product is safe. However, this requires a definition of safe processes. Taking microbial prevalence, number, heat tolerance and growth potential as well as consumer susceptibility and severity of disease into consideration three performance criteria (PC) have been suggested. For products intended for consumption shortly after cooking, at least 4 decimal reductions of *Listeria monocytogenes* must be achieved by heating. For heated products intended for consumption after chilled storage, the cooling down period must not result in more than 1 $\log_{10}$-increase of *Clostridium perfringens* and if the storage period exceeds 10 d at 3-5°C or 5 d at 5-10°C, at least 6 decimal reductions of psychrotrophic *Clostridium botulinum* must be achieved by heating. In order to be of practical use for the catering industry, these PC's had to be transformed into process criteria. For this purpose we developed models that can calculate process criteria, which fulfil the established PC's. For the heating process, two models were needed, one that calculated a theoretical pasteurization value (PV) that would result in a safe heating process, and one that converted an actual heating profile to a PV. Input variables for the theoretical PV calculation model are product type (fish, meat, vegetables, other), water phase salt content (≤ 3%, >3%), anticipated shelf-life and storage conditions (≤ 3°C, 5°C for max. 10 d, 5-10°C for max. 5°C, other) and end-temperature in the coldest spot of the product. Inputs for the PV conversion model are z-value for the specific product type, end-temperature

in the coldest spot and time/temperature measurements carried out during heating. For the cooling process, a process criterion stating that the product has to pass the interval from 50°C to 15°C in max. 3 h was determined. The model simulate the cooling profile of a product using three input variables i) product temperature in beginning of cooling, ii) cooling time and iii) product temperature after the given cooling time. The time that the product had spent in the interval from 50°C to 15°C is calculated and given as output. All models were constructed as simple Microsoft Excel spreadsheet models but have also been incorporated in e-Smiley, a Danish software for electronic self-inspection.

Background

According to the Danish catering industry, it is a challenge to keep a high culinary quality of for example certain fish and meat dishes because of the official requirements for safe holding either at hot or chilled temperatures. For heating, the Danish guidelines recommend a temperature of at least 75°C, in the coldest spot, if the company cannot document product safety by other means. Equivalently for safe cooling, the Danish guidelines recommend to cool down from 65°C to 10°C in max. 3 h. In both cases, the EU legislation opens the possibility to apply other time and temperature combinations as long as the company can document the safety of the product. However, this requires a risk-based definition of safe heating and cooling processes. For this purpose Codex has suggested a management concept named Performance Criterion (PC). PC is a transparent way to link a food safety program with its expected public health impact. Codex defines a PC as the effect on concentration of a hazard in a food that must be achieved by the application of one or more control measures to provide the wanted consumer protection (CAC, 2004). PC's for safe heating and safe cooling have, therefore, been established.

Performance Criteria – safe heating and cooling

Taking microbial prevalence, microbial number, heat tolerance and growth potential as well as consumer susceptibility and severity of disease into consideration PC's for safe heating and safe cooling have been suggested (Figure 1). Below each of the PC's is described in more detail.

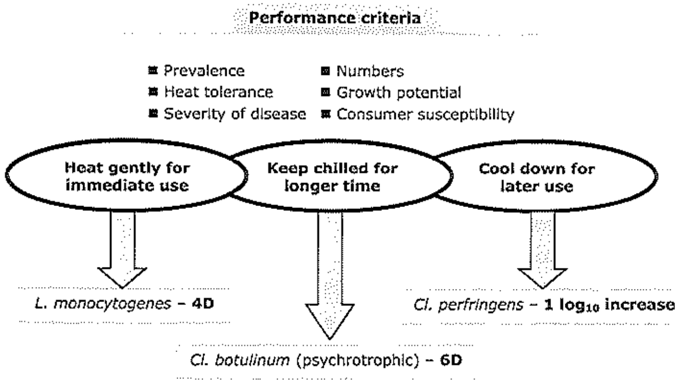

Figure 1. *Performance Criteria established for safe heating and cooling in the catering industry.*

For products, intended for consumption shortly after heating, it is not necessary to destroy pathogenic spore-forming bacteria, as relatively high levels are required to give rise to illness and there is no time for growth of these organisms before the food is served. Therefore, our model uses *Listeria monocytogenes* as the target hazard in this product category. *L. monocytogenes*, which is a frequent food contaminant, is among the most heat tolerant vegetative foodborne pathogens (Doyle et al., 2001) and can be fatal for certain population groups even in low numbers.

We know that *L. monocytogenes* levels in raw materials, such as fish, meat, vegetables, etc., rarely exceed 100 CFU/g (EFSA, 2009). Applying the EU food safety criteria (Anon., 2005), stating that *L. monocytogenes* has to be absent in 25 g ready-to-eat product when intended for susceptible population groups, we can assume that a safe heating process should be able to reduce *L. monocytogenes* from 100 CFU/g to less than 0.04 CFU/g. This reduction corresponds to at least a 3.4 $\log_{10}$-reduction, which we have chosen to raise to 4 $\log_{10}$-reduction – also referred to as 4 decimal reductions or simply 4D. A 4D heat treatment of *L. monocytogenes* has also been shown to limit the re-growth potential of heat-damaged cells considerably (Hansen & Knøchel, 2001). Hence, for products, intended for consumption shortly after cooking, at least 4 decimal reductions (4D) of *Listeria monocytogenes* must be achieved by the heating process.

For products, intended for consumption after chilled storage, the cooling down period has to be so fast that growth of any surviving pathogenic spore-forming bacteria is restricted. Therefore, our model focuses on *Clostridium perfringens* at this step. *Cl. perfringens* is among the fastest growing of the spore-forming pathogens and has the highest growth potential in the interval from 50°C to 20°C.

As discussed in Andersen et al. (2004) considering safe cooling of heated food, the initial levels of *Cl. perfringens* spores in ingredients become relevant. Foods highly contaminated with *Cl. perfringens* are reported to contain up to 4 $\log_{10}$ per gram (Labbé, 2000). As foods containing more than 5 $\log_{10}$ *Cl. perfringens* per gram are considered hazardous (USDA, 1999) the maximum acceptable increase during cooling can be 1 $\log_{10}$-unit. Hence, for heated products intended for consumption after chilled storage, the cooling down period must not result in more than 1 $\log_{10}$-increase of *Cl. perfringens*.

For products, intended for consumption after prolonged storage exceeding 10 days at 3-5°C or 5 days at 5-10°C, a more severe heating that destroys psychrotrophic spore-forming pathogens is needed. As long as the storage temperature is kept below 10°C, mesophillic *Clostridium botulinum* and *Cl. perfringens* do not grow. Therefore, our model uses psychrotrophic *Cl. botulinum* as the target hazard for heating within this category of products.

In 1992, the Advisory Committee on the Microbiological Safety of Food concluded that 90°C for 10 min, or equivalent 6D treatments, combined with chilled storage will ensure safety with respect to psychrotrophic *Cl. botulinum* (Peck, 1997). Hence, for heated products intended for consumption after chilled storage that exceeds 10 days at 3-5°C or 5 days at 5-10°C, the heating process must result in at least 6D of psychrotrophic *Cl. botulinum*. However, in order to be of practical use for the catering industry, these PC's had to be transformed into process criteria. For this purpose we developed spreadsheet models that can calculate process criteria, which fulfil the established PC's.

Process criteria – safe heating

For the establishment of process criteria for safe heating in the catering industry, we worked with the conclusion of Awuah et al. (2007), that establishment of safe heating processes should be based on two conditions; 1) the heat tolerance of target hazards for the specific product composition, and 2) the heating procedure of the specific product. Therefore, two models were constructed for the heating process. One model that calculate equivalent safe heating in the form of a theoretical pasteurization value (PV) that will result in a safe process, and one model that converts an actual heating profile, measured in the coldest spot of the product, into a PV describing the lethality of the process.

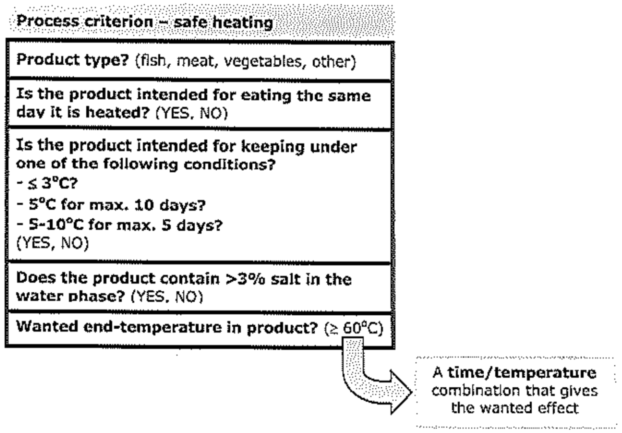

Figure 2. *Factors included in the theoretical PV calculation model for establishment of process criteria for safe heating in the catering industry.*

The theoretical PV calculation model is based on heat tolerance of the target hazards taking the specific product composition into consideration. Figure 2 shows the input variables for the theoretical PV calculation model are product type (fish, meat, vegetables, other), water phase salt content (≤ 3%, >3%), anticipated shelf-life and storage conditions (≤ 3°C, 5°C for max. 10 d, 5-10°C for max 5 d) and end-temperature in the coldest spot of the product. As the models do not cover end-temperatures below 60°C, classical log-linear heat inactivation kinetics is assumed. Heat tolerance

is, therefore, expressed as decimal reduction value, D-value, which is the time required at any temperature to destroy 90 % of a given microbial hazard. Plotting the logarithm of the D-value against temperature and fitting to a straight line by linear regression yields the z-value which is the negative reciprocal of the slope of this line and expresses the temperature change that will result in a 10-fold change in D-value (Awuah et al., 2007).

Product type was considered as a factor of relevance for the establishment of process criteria for the products intended for consumption shortly after cooking. Different heat tolerance has been found for *L. monocytogenes* in different foods (Doyle et al., 2001), which allow us to have different process criteria. This can be an advantage in regard to improving the eating quality of especially fish dishes. Also the salt content in the product may influence the process criterion in this particular product category, as heat tolerance of *L. monocytogenes* is considerably elevated if salt is present during the heating process (Jørgensen et al., 1995). Finally, the end-temperature in the coldest spot of the product will determine the time needed to obtain a safe heating process defined as a PV.

For products, intended for consumption after prolonged chilled storage, product type and salt content are only relevant if the storage conditions are designed to prevent growth of psychrotrophic *Cl. botulinum*. In practice this means that for products stored below 3°C, at max. 5°C for up to 10 d, or between 5 and 10°C for up to 5 d, the model uses D- and z-values for *L. monocytogenes* to calculate safe time/temperature combinations. For products that do not comply with these storage conditions, the model uses D- and z-values for psychrotrophic *Cl. botulinum*.

The PV conversion model is based on the concept of process lethality, also known from the canning industry as sterilization value or F-value (Awuah et al., 2007). We use the approach of target lethality and calculate the lethality of a specific heat process in the coldest spot of the product. Inputs for the PV conversion model, therefore, are z-value for the specific hazard and product type, end-temperature in the coldest spot and the actual time/temperature history measured in the coldest spot during heating. The following formula is used for the conversion of heating profiles to PV;

$$PV_{Tref}{}^{z} = \sum_{start}^{end} 10^{((T-Tref)/z)} \Delta t$$

where *t*, *z*, *T* and *Tref* represent the heating time (min), z-value of target hazard in specific product, temperature at any given heating time and end-temperature in the coldest spot, respectively.

In this target lethality approach, it is of utmost importance that the correct coldest spot is located. Factors that previously have been shown to influence the position of the coldest spot in relation to catering production are unequal product size (Hansen et al., 1995), unequal initial product temperature (Knøchel et al., 1997) and product location during heat processing (Hansen, 1996).

Process criteria – safe cooling

For the cooling process, a process criterion stating that the product has to pass the temperature interval from 50°C to 15°C in max. 3 h was determined on the basis of the work of Andersen et al. (2004). They found that growth of *Cl. perfringens* was less than 1 $\log_{10}$ unit if this criterion was fulfilled.

A model that simulates the cooling profile of a product using three input variables i) product temperature in beginning of cooling, ii) cooling time and iii) product temperature after the given cooling time was constructed. Based on the assumption that temperature profiles during cooling follow exponentially decreasing relationships, the model suggested by Blankenship et al. (1988) was used. The time that the

product had spent in the temperature interval from 50°C to 15°C is calculated and given as output along with a graph showing the simulated cooling profile (Figure 3).

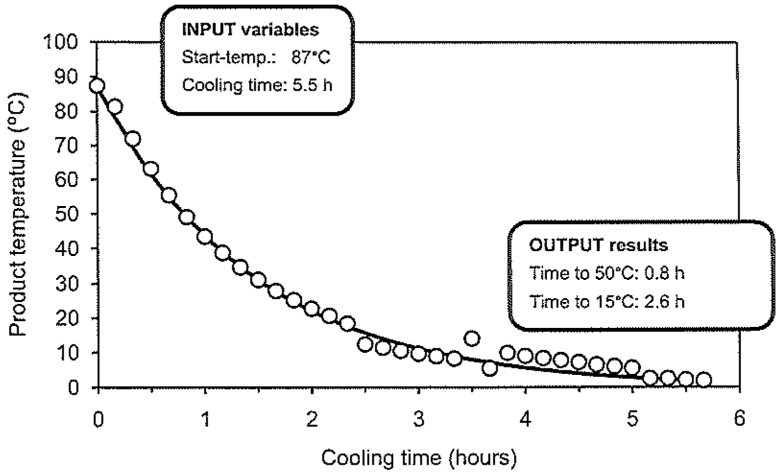

Figure 3. *Observed (O) and simulated (———) temperature profile for hot-filled rice pudding cooled in a rotating iced water bath.*

All three models were constructed as simple Microsoft Excel spreadsheet models but have also been incorporated in e-Smiley, a Danish software for electronic self-inspection.

Conclusions

The present work demonstrated a concept of applying Performance Criteria to define safe processes. Specifically Performance Criteria were established for safe heating and cooling processes in the catering industry. Furthermore, it was demonstrated how these Performance Criteria can be transformed into more practical process criteria by the use of computer models.

References

Andersen, K.G., Hansen, T.B. & Knøchel, S. (2004) Growth of heat-treated enterotoxin-positive Clostridium perfringens and the implications for safe cooling rates. Journal of Food Protection 67(1), 83-89.

Anonymous (2005) Commission Regulation (EC) no 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. Official Journal of the European Union L 338.

Awuah, G.B., Ramaswamy, H.S. & Economides, A. (2007) Thermal processing and quality: Principles and overview. Chemical Engineering and Processing 46, 584-602.

Blankenship, L.C., Craven, S.E., Leffler, R.G. & Custer, C. (1988) Growth of Clostridium perfringens in cooked chili during cooling. Applied and Environmental Microbiology 54(5), 1104-1108.

Codex Alimentarius Commission (CAC) (2004) Report of the 20th session of the Codex Committee on general principles, Pris, France, 3-7 May 2004, ALINORM 04/27/33A, APPENDIX II.

Doyle, M.E., Alejandro, S.M., Wang, T., Wiseman, D.W. & Scott, V.N. (2001) Heat resistance of Listeria monocytogenes. Journal of Food Protection 64(3), 410-429

European Food Safety Authority (EFSA) (2009) The community summary report on trends and sources of zoonoses and zoonotic agents in the European Union in 2007. The EFSA Journal 223, pp. 140-157

Hansen, T.B. (1996) Application of predictive microbiology in HACCP: sous vide and hot-fill technology. Ph.D. Thesis, Department of Dairy and Food Science, Royal Veterinary and Agricultural University, Denmark, November 1996.

Hansen, T.B. & Knøchel, S. (2001) Factors influencing resuscitation and growth of heat injured Listeria monocytogenes 13-249 in sous vide cooked beef. International Journal of Food Microbiology 63, 135-147.

Hansen, T.B., Knøchel, S., Juncher, D. & Bertelsen, G. (1995) Storage characteristics of sous vide cooked roast beef. International Journal of Food Science and Technology 30, 365-378.

Jørgensen, F., Stephens, P.J. & Knøchel, S. (1995) The effect of osmotic shock and subsequent adaptation on the thermotolerance and cell morphology of Listeria monocytogenes. Journal of Applied Bacteriology 79, 274-281.

Knøchel, S., Vangsgaard, R. & Johansen, L.S. (1997) Quality changes during storage of sous vide green beans (Phaseolus vulgaris). Zeitschrift für Lebensmittel Untersuchung und Forschung. A, Food Research and Technology 205, 370-374.

Labbé, R.G. (2000) Clostridium perfringens, p. 1110-1135. In: B.M. Lund, T. Baird-Parker & G.W. Gould (ed.), The microbiological safety and quality of food, vol. II. Aspen Publishers, Inc., Gaithersburg, Md.

Peck, M.W. (1997) Clostridium botulinum and the safety of refrigerated processed foods of extended durability. Trends in Food Science & Technology 8, 186-192.

U.S. Department of Agriculture, Food Safety and Inspection Service (USDA) (1999) Performance standards for the production of certain meat and poultry products. Federal Register 64, 732-749.

Addressing Short Term Heat Peaks on the Shelf Life of Minced Meat

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Keywords: shelf life, minced meat, predictive modelling, temperature response function, parameter estimation, initial value problems

Introduction

Minced pork meat decays rapidly as microbiological growth processes continue immediately after production and packing. However the potential shelf life can be extended from two to seven days by the use of MAP ("Modified Atmoshere Packaging") foil under favourable cold conditions from 2 to 4 °C. It is conceivable that food is temporaily exposed to high temperatures up to 50 °C during transport by the consumer. The question arises, how the shelf life of food is affected by such events. A common tool used to estimate shelf life is to model microbial growth as a function of temperature using the Arrhenius equation imbedded in some kind of continuous growth function. This approach is applicable to temperature regimes up to 20°C, but not valid at higher temperatures, as the system would exceed realistic growth rates. In order to consider high temperature exposures, a response model is required with recontoured slopes at higher temperatures.

Material and methods

MAP meat packages, taken directly from the producer, were stored both at constant temperatures in the range from 2 to 20 °C and partly exposed to temperatures of 20/30/50 °C, respectively for 3 hour periods at different points in time. Total microbiological contents (log cfu/g) were measured directly after delivery and continuously monitored in daily intervals for all trials, resulting in different growth dynamics with varying temperature scenarios. The constant temperature trials were imposed to identify the basic influence of temperature on microbiological growth, the latter ones, in total more than 30 combinations, to identify alternative response functions at higher temperatures.

To address the sigmoidal growth pattern of microbia dynamics including the common lag phase a logistical growth model is proposed as a parsimonous approach for modelling the time courses (after Richter, 1985). More complex models, as Richards, Gompertz (Richter, 1985) or Baranyi equations (Baranyi et al, 1993), are possible with respect to expected deviance