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Probabilistic evaluation of *Clostridium perfringens* potential growth in order to validate a cooling process of cooked dishes in catering

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ABSTRACT

The cook-chill operation, a widely used process within central cooking facilities, implies that cooked dishes have to be quickly cooled down immediately after cooking in order to prevent any food-borne diseases due to *Clostridium perfringens*. The food service operators are obliged to validate the efficiency of the cooling process in the context of their HACCP plan. To perform this cooling process, they can either ensure compliance with some reference criterion (maximal cooling duration) or demonstrate that the cooling operation is safe by carrying out prior tests.

This document presents an experimental method to validate the sanitary efficiency of the cooling process. In the studied kitchen the food was cooked and, successively, distributed into plastic containers, cooled down in blast-chiller and then stored in cold room.

The tests consisted in monitoring food temperature at the center of the containers from the end of cooking until the beginning of cold room storage. The measurements were performed during 6 cycles of food preparation.

From the monitored time–temperature profiles, thermal cooling equations were established for modeling.

Each parameter of these thermal equations was linked with a distribution fitted with the experimental data. Then these thermal equations were coupled with predictive microbiology equations. A probabilistic calculation of the *C. perfringens* potential growth was carried out by using @Risk software. The proposed method required only simple monitoring equipments and could be easily implemented in central kitchens under the usual working conditions.

The cooling conditions in the studied kitchen could be considered as satisfactory because the calculations give only a 0.4% probability that the *C. perfringens* potential growth was equal or greater than 1 log10 cfu/g.

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1. Introduction

In catering the cook-chill operation is often used: food is cooked, cooled down in a blast chiller immediately after cooking, stored in a cold room, then transported to the catering facilities and reheated just before serving. So the meal preparation is not related to the consumption time and therefore a food production in large quantities can be rationalized.

The cooling step must be quickly conducted to prevent germination of the bacterial spores which are not destroyed during cooking and multiplication of their vegetative cells. The cooling kinetics must be determined to avoid *Clostridium perfringens* growth: indeed it is the pathogenic spore forming bacteria which presents the fastest growth between 25 °C and 45 °C. Actually, many *C. perfringens* foodborne outbreaks have occurred (Greig & Ravel, 2009) and most of them are due to slow cooling operation or/and to cold storage without efficient refrigeration (EFSA, 2005; Pace, Duncan, Dowell, Antonmattei, & Wisniewski, 1976; Tallis, Ng, Ferreira, Tan, & Griffith, 1999).

Therefore it is quite important that the food service operators working in cook-chill operation make sure that the cooling process is fast enough to prevent any important growth of *C. perfringens*. To ensure that, they can either use criteria, for instance maximal cooling time between 2 temperatures, defined by regulation texts (JORF, 2009) or reference technical guides (USDA, 2001). If cooling time is higher than the reference value, it is necessary to ensure that *C. perfringens* growth cannot lead to dangerous levels. Such studies have to be carried out for the validation step of the HACCP method described in the ISO 22000 standard (2005).

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The validation of cooling step through microbiological analysis on finished products is not relevant. Tests using naturally contaminated foods are not possible: on the one hand the prevalence of this bacteria is often quite low (Augustin, 2011; Crouch & Golden, 2005) and on the other hand the multiplication of this bacteria is difficult to assess, because the initial spores amount cannot be known with precision. Indeed, only vegetative cells from spores can be enumerated, so the amount of spores which did not germinate remains unknown. Tests using artificial contamination can be carried out only in experimental conditions, because it is not possible to introduce pathogenic bacteria in a catering kitchen.

Predictive microbiology is more appropriate in that case. It allows predicting bacterial growth by combining a cooling profile to a microbiological model. Bacterial growth can be calculated using published models (Huang, 2003; de Jong, Beumer, & Zwietering, 2005; Juneja, Marks, & Thippareddi, 2008; Sanchez Plata, Amézquita, Blankenship, Burseon, Juneja, & Thipparedi, 2005; Smith-Simpson and Schaffner, 2005) or can be obtained directly thanks to websites like Combase or Symprevius.

The potential growth increment depends on several parameters, related on one hand to the disparity between the time–temperature profiles of the cooling process and on the other hand to the variability of the bacterial behavior. The deterministic method consists of calculating the potential growth with, for each parameter, the most favorable growth value. Thus, it is very likely that the actual bacterial growth is lower than the calculated results.

Nowadays tools for quantitative microbial risk assessment are available (Delignette, Cornu & AFSSA STEC study group, 2008, Pouillot et al., 2007) and recommended to validate control measures (Zwietering, Stewart & Whiting, 2010). These tools can take into account the variability of all parameters affecting bacterial growth. With the probabilistic method, the results express a probability of growth. The purpose of this paper is to present how to use a probabilistic method for the assessment of *C. perfringens* growth during a defined cooling process of cooked dishes in catering. The results are then compared with the ones obtained by a deterministic method.

2. Materials and methods

2.1. Materials

2.1.1. Characteristics of the studied kitchen and process

This study was carried out in a central kitchen using the cook-chill operation in a hospital in Paris. Immediately after cooking, the food was quickly cooled down, and then stored in a cold room for two or three days. It was then reheated just before being served to the patients.

This kitchen was selected because of this operating mode which was representative of many hospital central kitchens on one hand and of its effective management system regarding the cooling process, already set up on the other hand. This kitchen prepared about 1300 meals a day distributed into 40 care units.

The study concerned a beef-in-sauce preparation. The gravy ingredients and meat were cooked in a large frying pan during 1 h 30 at 95 °C. Then the food was split into plastic containers (dimensions: 530 × 325 × 65 mm), each containing 12 to 15 servings, i.e. around 2.5 kg. These containers were closed with a plastic film after a variable waiting time at room temperature and then randomly laid on a stainless steel trolley which was next wheeled into the blast chillers and then stored in the cold room. The kitchen is equipped with 3 convection blast chillers connected to a central remote condensing unit.

2.1.2. Cooling characteristics

The cooling process begins when the food preparation was taken out of the frying pan and could be divided into four separate stages: the waiting time before closing, the waiting time after closing, the cooling down in blast chiller and the storage in the cold room.

The waiting time before closing is the time between the splitting of food into containers and their closing.

The waiting time after closing is the time between the closing of containers and their introduction into the blast chiller. Closed containers were laid without any precise loading plan, on a 20-shelves trolley, on the basis of 2 containers on each level. The load on the trolley varied between 30 and 46% of its capacity with an average of 38%. Once one of blast chillers was available, the trolley was wheeled therein.

The periods of waiting before and after the closing time may vary from one production to another depending on several factors: (i) working organization depending on the number of operators and the availability of those assigned to the containers closure or to the setting up of blast chillers, (ii) the quantity, the variety or the complexity of the other cooked food being prepared, (iii) the lack of availability of blast chillers during days of intense production inducing long waiting time before the introduction of the trolley into the blast chiller.

All these production hazards generated a large variability of duration for these first two stages.

The cooling down period in blast chiller: the blast chiller was piloted by a manual thermometer probe, inserted by the operator into a piece of meat which was placed at the geometric center of the container laid at half of the trolley height, at front position. As soon as the measured temperature in this piece of meat reached 8 °C, the compressor of the blast chiller stopped, which corresponded to the end of the cooling down cycle. The location of the temperature measurement at the container geometric center is important for a good control of the cooling down operation. Indeed, a previous study (Poumeyrol, Morelli, Noel, & Cornu, 2012) highlighted that a stop of functioning of blast chiller controlled by a temperature measurement made anywhere in a container induces a significant dispersion of food temperatures at the end of cooling down cycle. In that case the temperature can be high and an average temperature of 25 °C at the geometric center of the containers was observed in 5% of cases.

The cold room cooling stage: the containers were stored into a cold room just after the end of the cycle of the blast chiller. The transfer of containers between the blast chiller and the cold room is fast and has no significant influence on the food temperature.

2.2. Methods

The *C. perfringens* potential growth was calculated by linking thermal equations, which simulate food cooling, with predictive microbiology models. During the tests in the kitchen, the aim of the measurements was to collect the data required to quantify the thermal equations parameters.

Bacterial growth calculation took into account the effect of the criteria of blast chiller piloting, i.e. the cooling cycle ends when the temperature measured by the probe is equal to 8 °C.

2.2.1. Nature of the tests

The temperature of food was measured from the filling of containers until the storage into the cold room, i.e. during the four stages described above. The tests are performed under the usual working conditions of the kitchen.

The temperature of food was monitored using thermo-button, an independent time temperature recorder (Proges-Plus, Willems,

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