DESIGNING THE CONTROL FOR SAFE HEAT TREATMENT OF CANNED FOOD

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Abstract: *Heat treatment is used to prevent the microbiological danger. That is why strict operating procedures are used to control the proper workflow, whose violation may have serious consequences. The operation can be considered a critical point in terms of food safety. The hazard prevention is more effective if the temperature of the heat treatment is higher or the duration of the intervention is longer. If the can is exposed to a high temperature for an extended time, or the product is cooked further, its quality will be worse. Therefore, the heat treatment procedure has to be defined and the controlling has to be established so that the process complies with the safety and quality requirements.*
More advanced control can be applied with sufficient instrumentation if the cold point temperature of the can is available during the heat-treatment process. In this case, by controlling the process shutdown based on one of the continuously calculated heat treatment equivalent (for example the F_0), the product will not only be safer but its quality will be better preserved as well.
Keywords: *canned food, heat treatment, food quality*

Introduction

Safety and quality appear as primary criteria in food industry researches. Applied research in the area of "minimal processing", i.e. gentle processing procedures, has greatly contributed to supplying safe products for customers (Biacs 1998; Goldberg 1994; Kiss 2000; Farkas 2001). The goal is to minimize the intervention, the treatment and the preservation of the food to retain the original features, the enjoyment and nutritional value. In addition, consumers want a product that is easy to use, can be stored for a long period, needs less culinary activities until put on the table, safe and free from disease-carrier micro-organisms and preservatives (Bíró and Bíró 2000).

Food security is a complex criteria system and when fulfilled, the consumed food is not harmful to health, does not impair the quality of life, does not cause harm to the customer and it does not reduce his or her working capacity (Biacs 2003). Quality is a broader concept than safety (nutritional and enjoyment value), but cannot do without security. It means the fulfilment of conditions, which serve as a basis of market sales potential and represent market value. Only safe goods are to be sold on the market (Biacs 2005).

The heat treatment is done in autoclaves, which are closed and pressure retaining devices. They can be vertical or horizontal constructions and can be uploaded with rolling cargo units or baskets on rails. During their operation, the specified duration and the temperature of the three-phased heat treatment (heating up, hold time and cooling) is controlled with automatics by supplying heating steam and cooling water.

Material and method

Food spoilage is most often caused by a variety of microorganisms. The primary task of the heat treatment is to prevent the microbiological threat. Higher temperature result in a faster microbial degradation, so in terms of safety, a short-term and higher temperature treatment may equal to a longer term treatment at a lower temperature. However, these two equivalent treatments result in a product of different quality and value. Usually, the shorter treated food preserves more of the valuable characteristics more important to the customer. Too high temperature, however, inhibits shortening the time of the treatment.

In order to reduce the heat damage of the surface, lower temperature but longer duration treatment is used in the case of solid products which warm up by heat conduction. In this case, less heat gets inside the product during a unit of time, thereby the heat, which is not carried away from the surface, decreases and therefore the level of damage, the heat shock, resulting from the overheating of the surface will not be so high (Eisner 1979).

The microbiologically required minutes for heat treatment on a given temperature (250°F=121.1°C for sterilization according to an agreement) were determined for product types, based on the amount of microorganisms, to ensure commercial sterility. The heat treatment then can be scaled based on the obtained equivalent (F-value) (Deák et al. 1980). As a result, comes the specification called the sterile-formula, with the following form:

$$\frac{30-45-25}{118} \quad (1)$$

The top three numbers, respectively, mean the number of minutes of heating, holding and cooling, while the number below shows the temperature to be reached (Szenes and Oláh 1991).

The practical problem of determining the sterile formula is that the heat treatment should be scaled to the slowest warming point (core and cold point) of the canned food, usually the geometric centre of the package, because if this point receives adequate heat load, all the other points cannot receive less. However, it is not clear, where to find this point (Flambert and Deltour 1972; Uno and Hayakawa 1979; Körmendy and Körmendy 2007) and how the temperature of the cold point follows the outside temperature (Campbell and

Ramaswamy 1992). For safety reasons it is, therefore, advisable to measure the temperature of the cold point as well and to take into account a continuously calculated heat treatment equivalent.

Results and discussion

People have been examining the destruction of microorganisms caused by heat treatment for almost a hundred year. Bigelow and his colleagues worked out the basics of heat treatment scaling (Bigelow et al. 1920; Bigelow 1921; Bigelow and Esty 1921). The degradation of the most important microorganisms caused by humid heat can be described with a negative exponential relationship, according to which, after successive and equal heat treatment durations, always the same proportion of the actual initial viable colony count. The D-value represents the time to decline to the tenth, usually in minute units, which is strongly influenced by the type of microbes and the used temperature. The D-value is only evident when the corresponding reference temperature (Tr) is given, for example: D65 decimation period at 65°C (Novak et al. 2003; Deák 2006; Zhu et al. 2008).

The speed of microorganism destruction varies with temperature. The z-value is the temperature increase in degrees Celsius belonging to the reduction by an order of magnitude of the decline to the tenth (D) (Deák 2006). This value allows the comparison of heat treatments with different temperature and duration (Kovács 1997):

$$\frac{D_T}{10} = D_{T+z} \Rightarrow \frac{D_T}{D_{T+z}} = 10 \Rightarrow \frac{D_T}{D_{T+n\times z}} = 10^n \tag{2}$$

Since T can be any temperature, therefore

$$T_r = T + n \times z \Rightarrow n = \frac{T_r - T}{z} \tag{3}$$

Based on (2)

$$\frac{D_T}{D_{T_r}} = 10^{\frac{T_r - T}{z}} \Rightarrow D_{T_r} = D_T \times 10^{\frac{T - T_r}{z}} \tag{4}$$

Let t denote the duration of the heat treatment at T temperature, which reduces the viable colony count with an “m” order of magnitude that is:

$$t = m \times D_T \tag{5}$$

Then, based on (4):

$$m \times D_{T_r} = m \times D_T \times 10^{\frac{T - T_r}{z}} \Rightarrow F = t \times 10^{\frac{T - T_r}{z}} \tag{6}$$

That is, we get the F equivalent which expresses that a heat treatment with t duration and T temperature is equivalent to how long treatment at the reference temperature (T_r=121.1°C=250°F for sterilization). The

$$F = m \times D_{T_r} \tag{7}$$

expression, that is, the desired F-value during the heating is usually determined by applying the principle of D in the case of the most heat resistance microorganism (Clostridium botulinum, D=0.21 minute) of this product type. The worldwide adopted method for foods with greater than 4.5pH value (such as meat) is to use heat treatment for sterilization for health reasons which causes the destruction of Clostridium botulinum spores at twelve orders of magnitude. This is the so-called 12D principle (Szenes and Oláh 1991). For this, 12×D minutes, namely, at 121.1°C a 12×0.21=2.52 minutes heat treatment period is needed (the F-value of Clostridium botulinum is therefore 2.52 minutes). Typically, it is considered to start the heat treatment from 10^6 viable colony count per gram. Reducing this by twelve orders of magnitude, the 10^{-6} viable colony count per gram means, that there can be one viable bacteria in 10^6 grams. The conversion mode given in formula (6) for F equivalent cannot be used in practice, because T core temperature changes constantly during the heat treatment. If the whole treatment is divided into periods with sufficiently fine size, the temperature can be considered constant in these Δt long phases. In this case, the heat treatment equivalent (F) can be calculated in the following practically applicable way:

$$F \cong \sum_{i=1}^{n} 10^{\frac{T_i - T_r}{z}} \times \Delta t \tag{8}$$

where:

n – number of intervals

T_i – temperature at the i^{th} interval

By refining the division beyond all limits, the calculation of F's theoretical formula is:

$$F = \int_{t_s}^{t_e} 10^{\frac{T(t) - T_r}{z}} dt \tag{9}$$

where:

t_s – start time,

t_e – end time,

T(t) – core temperature as function of time.

Other equivalents can be obtained with different Tr and z values by using the same calculation methods as in the case of F-value:

$$F_0, C, E = \int_{t_s}^{t_e} 10^{\frac{T(t)-T_r}{z}} dt \tag{10}$$

The F_0 is the special case of F, when z=10°C is applied which should be used in case of Clostridium botulinum spores. The E is the enzyme activity equivalent and C is the cook equivalent. The latter is important when the goal of the heat treatment is to change the organoleptic characteristics in addition to ensuring durability. Thus, in order to achieve the desirable taste, colour etc., a heat treatment exceeding the specified C-value is necessary. The heat damage of food and the strong organoleptic alteration can also be characterized by the C-value (Szenes and Oláh 1991). So, a too low or too high C-value has bad impact on the quality assessment of the product.

As it could be seen in the literature review, when defining the requirements of the heat treatment, the so called sterile formula, tests are carried out in laboratory conditions and during the calculations, great care is given to choose the most favourable heat treatment with equivalent microbial destructions in terms of product quality. If the manufacturing practices of the heat treatment differ from this specification, then, in more severe cases, the product will not be safe, that is, the required degree of microbial destruction will not be reached. The product will be spoiled before the expiration date causing great damage to the consumer perception of the entire company. The consumers may lose their trust and turn away from the other products of the company as well and thus the firm's existence may be threatened. The company will have to bear all the legal consequences of the damage caused in the consumers' health by the spoiled food. If the heat treatment differs from the process defined by the sterile formula, in milder cases, the quality of the product will deviate from the optimal to greater or lesser extent. For these reasons, autoclaves are equipped with the appropriate instrumentation and are able to automatically provide the heat treatment process according to specifications without human intervention. In case of a temporary failure of the steam supply, the automatics cannot heat up the equipment within the provided period, or keep the temperature by controlling the openness of the steam valve, or cannot ensure the adequate cooling phase in the absence of the required intensity of the cooling water. These problems may occur because the more resource-intensive phases of the heat treatment process can come together in the several autoclaves operating in parallel. It is the task of the automatics to even then, as a top priority factor, guarantee the safety of the product. Given its importance, the operation of the automatics in each of the three phases (heating, hold time and cooling) is the following:

At the beginning of the heating, the automatic system determines the necessary temperature increment per minute. To do this, it measures the initial temperature and then extracts this from the temperature to be reached given in the sterile formula and divides this by the duration of the required heat-up time.

It tries to keep the temperature increase in a linear fashion with this steepness. It cannot solve the gap due to steam supply problems by increasing the slope because a more intensive temperature increase is harmful to the quality of the product. This means that to ensure the quality of the product the duration of this phase can only be longer than specified, but not shorter. The result of the longer heating time is a lower quality product with higher cook-equivalent (C-value), but the quality is less bad than it would be in case of applying more intense increase of heat than specified.

The hold time should only start when the required temperature is reached and it cannot be less than specified, even if the period of the heat up time has increased. Of course, in this case, the duration of the hold time could be shortened due to the more intense microbial destruction achieved during the heating, but to a lesser degree than the increment of the heat up time and a complicated, temperature dependent calculation would be necessary to compute the exact value. The reason for this is that at a lower temperature, a longer period is necessary for the same amount of destruction. However, due to insufficient steam supply, the duration of this phase can be increased with the time when the required temperature could not be maintained. In this way, the hold time ensures the microbiological safety of the product.

Upon cooling, there are no product safety concerns. However, the controlling is different depending on whether the autoclave uses water bath or water spray during the cooling process and whether the internal temperature of the can (core temperature) or only the coolant temperature (compartment temperature) is measured. When using water bath, the linear reduction of the compartment temperature can be achieved until the desired 40°C is reached but only by setting the slope of the cooling, just as in the heating up phase. Therefore, in this case, the cooling time may increase. When applying spraying technique for cooling, the compartment temperature drops immediately and the phase lasts for the specified time or longer, until the core temperature is above 40°C. If the core temperature is not measured, the heat treatment may be completed at the scheduled time, but the product may have a higher temperature.

However, the duration of the heat treatment can be reduced in many cases and thus the energy consumption will be less and also the product will suffer less damage. So two objectives can be achieved with the appropriate instrumentation, with the real-time computer control, when, after reaching the required heating, the hold time ends based on the continuously calculated F0 equivalent and the cooling phase starts, thus preventing overtreatment (Teixeira and Tucker, 1997; Simpson et al., 2006a, 2006b, 2007). Then the actual value of F (F(n)) is calculated automatically at Δt intervals from the previously calculated F-value (F(n-1)) and the actual temperature (T) in the following way:

$$F^{(n)} = F^{(n-1)} + 10^{\frac{T-T_r}{z}} \times \Delta t \tag{11}$$

where:

T_r – reference temperature

The automatics will stop the heat treatment when the calculated actual value becomes higher than the specified F_0 equivalent.

Conclusions

Based on the above, it can be stated that the automation ensures the microbiological reliability of the product even in the case of inadequate resource supply, but this is done by either increasing the length of the phases or by producing a higher temperature end-product. These problems, however, result in a smaller or greater deviation from the optimal product quality defined in laboratory conditions. If the can is exposed to a high temperature for an extended time, or the product is cooked further, its quality will be worse (in more severe cases it thickens, changes colour etc.).

All these disadvantages can be prevented if the controlling is carried out by not only applying the sterile formula, but also complete it with a continuously calculated F_0 value.

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