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Influence of Thermal Properties of Canned Containers and Food Products on the Parameters of the Sterilization Process

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Relevance

In the food industry, food products are packaged in three main types of cans: glass, metal, and polymer. Different types of container material, product consistency have different thermo physical properties that affect the parameters of the heat treatment process, when developing canned food sterilization modes. Time sterilization is one of the main microbiological parameters of heat sterilization, which affects the microbiological stability of canned food during storage, ensuring industrial sterility of the product, the absence of microbiological defects in products and food poisoning. This parameter is fixed in the sterilization formula for a certain type of product and container and is approved in the technological instruction.

Sterilization Process Parameters

The sterilization time τ_{ster} consists of two components - the time it takes to destroy microorganisms in the center of the sealed container with the product (at the point of the worst heating), it is called lethal or lethal τ_{dead} (this is a microbiological component) and the heating time τ_{warm} of the product with the product, or the time it takes to reach the sterilization temperature in the center of the can (this is the thermo physical component of the sterilization time): $\tau_{ster}=\tau_{dead} + \tau_{warm.}$

The type of product and its thermo physical properties, which depend on the consistency, affect the sterilization time and heating time. When sterilizing canned food of liquid consistency (juices, drinks), in which the heat is transferred by means of convective currents, heating occurs quickly and intensively [1-3].

Influence of Various Factors on the Thermo Physical Component of the Sterilization Time

There are foods with a thick consistency, for example, tomato paste, mashed potatoes, jams, pates, in which heat transfer is carried out in a conductive way, mainly by heat conduction. The thermal conductivity of such food products is small and heating is slow. There is an assortment of canned food of heterogeneous composition, two-component types of compotes, marinades, consisting of a liquid part (syrup, bay) and a solid part (prepared vegetables, fruits).

For this option, heat transfer occurs in two ways: convection and thermal conductivity and convective currents during heating, prevail here. In terms of heating intensity, this canned food occupies an intermediate position, but closer to the first group, liquid in consistency. It has been experimentally proven that when sterilizing canned food in autoclaves, the heating of any product lags behind the heating of the autoclave and the maximum temperature in the can with the product is reached later than in the apparatus and its value is several degrees lower than the sterilization temperature. Also, the moment of the start of product cooling is delayed relative to the start of cooling of the apparatus. The difference in heating temperatures for liquid and thick products is about 20%.

To quantitatively compare the heating intensity of products with different thermo physical properties, the exponential portions of the heating curves (in the coordinate system temperature-time) were "straightened" by mathematical processing in semi logarithmic coordinates, which made it possible to characterize them with a simple expression: $\lg ((T_a-T_{in})/(T_a-T_f))=\tau/fh$ (1).

where-T_a, Tin, T_f are the autoclave temperature, the initial and final temperature of the product during sterilization, respectively, $^oK\tau$-Time of reaching the highest temperature in the depth of the product, min f_h-constant of thermal inertia of the product-this is the time during which it is necessary to warm up the product so that the temperature difference between the apparatus and the product is reduced by 10 times, min. The larger f_h, the longer is the time required for complete heating of the product and f_h is a measure of thermal inertia, and equation (1) is the equation of thermal inertia, which can be written as: $\tau=f_h * \lg ((T_a-T_{in})/(T_a-T_f))$.

For liquid foods, f_h is significantly less than for thick ones, and it is possible to quantitatively compare the heating of foods of different consistency. For example, for the same type of container, f_h for grape juice and green peas is 15-25 minutes. Thick products have f_h: tomato juice-55 min., tomato puree-80 min., tomato paste-90 min. It can be concluded that the transfer of heat during the sterilization of liquid food products, grape juice, occurs by convection, and during the sterilization of thick products, such as tomato paste, pates, it is carried out by heat transfer (thermal conductivity). The maximum value of all food products is tomato paste; other products occupy an intermediate position-the higher f_h, the thicker the product, the more conductive heating prevails. Before heating the product, the heat must overcome the thermal resistance of the container material itself, the thickness of its wall σ, which depends on the ratio of the wall thickness and its thermal conductivity: the thicker the can is and the lower its thermal conductivity, the greater its resistance [1-3].

The purpose of the work is to show by calculation the influence of the type of container and the consistency of the product on the thermo physical component and the effectiveness of the sterilization process. The wall thickness of the metal container is very small δ=0,0002-0,0003 m, the thermal conductivity of the metal is high and equal to λ=47-52 W/(m^{*o}K) and the thermal resistance of such a can is, on average, σ=δ/λ=0,5*10-5^{o}K/W. This is a small value and is not influenced by fluctuations in the wall thickness of the metal container and cannot significantly affect the thermal resistance of the can wall.

The wall thickness of the glass container is 10 times greater than the thickness of the metal container and is equal to δ=0,002-0,006 m, the thermal conductivity of the glass is low, about λ=0,6-0,9 W/(m^{*o}K), i.e., 80-90 times less than the thermal conductivity of tin and the thermal resistance of glass is significantly σ=δ/λ=0,01^{o}K/W and significantly changes from fluctuations in the thickness of the container wall. If we take σ for metal containers as 1, then σ for glass containers will be 1000 such units. Consequently, fluctuations in the wall thickness of glass cans have a very significant effect on its thermal resistance. And it is very important in the production of glass canning containers to control this indicator of the quality of cans for compliance with its requirements of the current regulatory document and it is imperative to control these values during the incoming inspection of glass containers at canneries, because it depends on heating efficiency, microbiological stability of the canned product.

Polymer containers made of polyethylene terephthalate have thermal conductivity λ=0,14 W/(m^{*o}K), δ=0,0001 m, not less, then σ=δ/λ=0,0007^{o}K/W. Semi-rigid polymer packaging lamister, which is made from a combined sterilizable material based on aluminum foil and polypropylene, has higher thermo physical properties than metal packaging due to the high thermal conductivity of aluminum λ=236-240 W/(m^{o}K), which is approximately 5 times more than tin. We are interested in the thermal resistance of the container wall only in combination with the time of penetration of heat into the depth of the product during sterilization of canned food [4,5].

In practice, there are options: Sterilization of a liquid product in a metal container, when heat exchange is convective from the coolant to the container wall (heat transfer coefficient α_1), then heat is transferred heat conductively through the container wall and then heat convectively goes from the container wall to the product (heat transfer coefficient α_2) $\sigma=1/\alpha_1 + \delta/\lambda + 1/\alpha_2$.

Calculations have shown that the values $1/\alpha_1$ and $1/\alpha_2$ are small, since α_1, α_2, as a rule, are rather large. The thermal resistance of such a system is even less important. Therefore, thermal resistances are distributed in a ratio of 100:1:100 and for the time of penetration of heat into the depth of such a product, the influence of the physical properties of the product and the physical properties of the container is practically equal (α_1 of a metal container has 100 units out of 201 units of the entire system).

Sterilization of a liquid product such as juices, drinks, fruit and vegetable puree in glass containers has a ratio of thermal resistance 100:1000:100; the heating time of such a container is several times longer than in the previous version (here a total of 1200 units) and the heating time of a liquid product in glass containers is mainly influenced by the physical properties of the material of cans, and not the product, since in the system of thermal resistance the container-product has a maximum share falls on containers (1100 units out of 1200). Sterilization of a thick product such as tomato paste, pâtés in metal containers. The heat in the product is distributed mainly through thermal conduction. The movement of heat in such a system can approximately be considered through a complex wall, consisting of two layers- "metallic" and "product". In this case, the transfer of heat to the center of the container proceeds according to the scheme-convectively from the heat carrier of steam to the wall of the container, then through the container wall and thick product (product wall) conductively, that is, through the thickness of the product to the center of the container.

The thermal resistance of such a system is $\sigma=1/\alpha_1 + \delta/\lambda + \delta_{prod} /\lambda_{prod}$. Since the thickness of the product wall is several hundred times greater than the thickness of the metal wall and λ_{prod} (about 100 times) is less than λ_{metal}, it has a thermal resistance ratio of 100:1:25000, the heating time of such a can is longer than the heating time of a container with a product where heating is convectively and the heating time is influenced exclusively by the physical properties of the product, since in the container-product thermal resistance system, almost the entire absolute value of the thermal resistance falls on the product. When sterilizing a thick product in a glass container, the ratio of thermal resistance for this system is 100:1000:25000 and the time for heat penetration into the center of such a container is long and is determined solely by thermal resistance, the consistency of the product, since in comparison with it, the container accounts for 4%. Polymer containers occupy an intermediate position in thermophysical properties between glass and metal containers [6].

Conclusion

The thermal resistance of the container and the thermo physical properties of the product when developing the modes of heat sterilization of canned food is important only in conjunction with how it affects the time of heat penetration to the point of the worst heating of the product. Depending on the type of product and the type of container, heating occurs in different ways-convective or conductive and the heating time of the container with the product during sterilization will be different, more or less. Therefore, these factors must be taken into account, otherwise, the heating time and, accordingly, the sterilization time canned food in the sterilization formula will not ensure industrial sterility of the product, which is fraught with food poisoning, massive microbiological rejects and losses for food enterprises. Calculated data showed that it is most effective to sterilize thick products in a metal container (option 3), since in this case the thermal resistance falls on the product, and the metal container has the lowest thermal resistance compared to glass and polymer containers. This will reduce the duration of heat sterilization of the product, which will lead to maximum preservation of the quality of canned food.

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