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## CANNING FOOD IN SEMI-RIGID POLYMERIC AND COMPOSITE CONTAINERS

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**Introduction. Formulation of the problem**

The research considers using different types of polymeric and composite containers for packaging operations in the food industry. The progress in developing polymeric packaging materials for long storage of food in the food industry depends on how effective polymers are and how efficient and economically feasible their production is. Food manufacturing is highly demanding of containers and packaging methods. Besides its main function of keeping goods fresh for consumers as long as possible, packaging is to solve other tasks, which are as important: it is supposed to make a product attractive in appearance, easy to transport, store, and sell. When manufacturing foodstuffs in long-storage polymeric containers (canned food), a vital question is heat-treating these containers using sterilisation equipment of various types. In this case, the technological parameters of food and packaging are highly important: closure strength, temperature of packaging the product, hermetic sealing, and, of course, technological adaptation of various composite polymer containers to heat treatment on sterilisation equipment of different types. These topical

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**Abstract.** For thermal preservation of food, various types of retail polymeric packaging can be used: rigid, semi-rigid, flexible, and other kinds of containers. To make polymeric (plastic) containers usable for thermal sterilisation, and to ensure long storage of food, they should have a barrier layer that will make them heat-resistant, prevent oxygen ingress, and preserve the product's quality and nutritive value. Every polymer material has its individual heat resistance characteristics. This paper considers such retail containers for food packaging as a composite can made of metal with a plastic lid and a semi-rigid heat-resistant polymer container with a foil cover. When using different container types for heat sterilisation and prevention of physical defects in cans, the following technological characteristics of cans should be taken into account: closure strength, depressurisation pressure, method of closure, diameter of a container's opening, absence or presence of a stiffness relief on the cover, temperature of packaging, and other factors. The research includes analysis of existing types of retail composite and polymeric containers for canning food using different heat sterilisation methods. The theoretical and experimental research conducted has resulted in obtaining the values of the closure strength of the containers, an important parameter without which proper heat sterilisation of a product would be impossible. Developing scientifically proved parameters and modes of high-temperature sterilisation of meat and fish products in semi-rigid heat-resistant composite metal-plastic containers will allow enterprises to manufacture high-quality and safe canned food with high nutritive value.

**Key words:** sterilisation, technological parameters, containers, closure strength, depressurisation pressure.

questions are the ones this research is based on, and without solving them, it is impossible to introduce industrially new types of packaging and obtain high-quality food products that will become popular with consumers [1].

**Analysis of recent research and publications**

Nowadays, food packaging materials are polymers, paper, cardboard, metals, glass. Containers used in canning are of the three main packaging types: glass, metal, and polymeric.

Polymeric food containers make up to 40% of the market, because this packaging type is favoured by consumers nowadays. Polymers belong to the cost-effective materials that can, in some cases, be used instead of tinplate and glass to make canning containers.

This group includes items made of polystyrene (beverage cups, containers for different foods irrespective of their consistency), polypropylene (cups for fermented milk products), polyvinyl chloride (containers, bottles), polyethylene terephthalate (containers for salads and bulk products), aluminised

foil and plastic bags, composite multilayer containers, the basic materials of which are the copolymer polyvinyl acetate, polyethylene, and others (flexible containers, bags, film bags). These materials have a number of advantages: they are low-cost, easy to recycle and transport, can be used in the manufacture of quite a range of different articles. That is why plastic products are now used most widely. The main downsides of this consumer packaging is its low environmental safety, sunlight permeability, quite high gas permeability [1].

Polymeric packaging for food can be classified in a number of ways. By its purpose, it falls into shop distribution containers, workshop containers, and retail (consumer) containers. By its construction, it is classified as bottles, containers, boxes, etc. By its compactness, packaging can be collapsible, dismantlable, and non-dismantlable. Depending on the materials used (and on the mechanical durability and degree of firmness determined by the material), there are rigid, semi-rigid, and flexible means of packaging.

Rigid polymer containers, when filled with products, retain their original shape and size. They can withstand mechanical impacts while transported and stored. This category comprises barrels and crates. This type of food packaging protects its content from mechanical impacts, and in some cases, from the action of oxygen, microbiota, ultraviolet radiation. Rigid polymer containers can withstand temperatures higher than 100°C, so for them, the following thermal sterilisation methods are used: hot filling, pasteurisation, sterilisation [2-4].

Semi-rigid packaging includes composite cardboard polymer containers like semi-rigid polymer cups, cans, pallets. They can be single-sectional and multisectional, made of multilayer polymers (polypropylene, polyvinyl chloride, shockproof polystyrene, a number of copolymers and co-extrudates) with high barrier characteristics. These materials are used for sterilised foods, such as canned meat and fish and the like. Thin covers for these containers are made from aluminium foil with a thermoplastic or thermoform lacquer to seal the container airtight by heat sealing. This packaging type only retains its original form when under a light load. Semi-rigid composite polymer-coated cardboard containers with aluminium foil as a barrier layer make a group that includes packaging of different shapes and sizes like Tetra Pak, Tetra Brik, Tetra Prisma, and others. These containers range from portion-sized tetrahedral packages (Tetra Classic, with the volume 20-65 ml) to rectangular packages, sometimes equilateral in section, with the volume 0.2, 0.3, 0.5, and 1.0 litre (some are 1.5-2 litres in volume). They are not heat-resistant, so the heat sterilisation method that can be used for them is aseptic preservation [1-4].

For composite packaging, the systems Tetra Pak, Tetra Brik, Tetra Prisma, and Combibloc use roll materials and combine, in one process, sterilising the

packaging material, moulding the containers, making them, filling them with products, and sealing. The airtightness of a modern aseptic carton for beverages is ensured by its five-layer structure: the outer polyethylene layer, cardboard, the middle polyethylene layer, the layer of aluminium, and the inner polyethylene layer. Aseptic cardboard used for beverage cartons has high barrier characteristics that allow storing products for quite a long time (up to 10-12 months) under no special storage conditions, with no preservatives used, and without any deterioration in the quality or taste. The term 'composite packaging' denotes both the structure of the material a container is made of and the materials themselves, their different types (e.g. a metal can with a polymeric cover, or a polymeric container with a cover made of lamister) [4,5].

To manufacture canned food preserved by the thermal sterilisation method, the containers used are made from polyethylene terephthalate (PET), polyethylene, polypropylene, Polyamide 11, and other heat-resistant polymers. In this case, sterilisation is complicated by backpressure modes in autoclaves, since to prevent inflation of packages, the pressure in the apparatus must be higher than that in the container throughout the whole cycle [6,7].

PET containers can withstand not very high packaging temperatures (70–75°C). At higher temperatures, a bottle deforms irreversibly. To manufacture PET packaging, the company Constar International uses the three-layer structure of polymer with a barrier layer of Nylon-MXD6 and oxygen absorber. This passive-active barrier system called Oxbar is designed to package juices, hot-fill products, and beer. Constar bottles are designed to be strong enough to go through tunnel pasteurisation. To this end, their necks are elongated and can expand to relieve the pressure, and their main structure retains its shape and the closure strength. The thermostability limits of PET, though, are critical for hot filling or pasteurisation. Kosa, a supplier of polyester, solves this problem using the copolymer PET Polyclear 2201 and the copolymer PET/PEN Polyclear 2202. Each of them is more thermostable than common PET. It has been reported that Polyclear 2201 can withstand up to 1,980°F (920°C), which is far beyond the ordinary hot filling range, and Polyclear 2202 can withstand up to 2,030°F (950°C). This is quite enough for some packaging types that undergo pasteurisation. To preserve food (juices, beverages, sauces, spices, pastes, ketchups, beer) in PET containers, different heat sterilisation methods are used: aseptic canning, hot filling (for liquid and pastelike products), juice pasteurisation [8,9].

Flexible polymeric packaging containers are the most preferred by consumers. In these containers (they can be transparent or non-transparent), food can be stored for a long time without refrigeration. An excellent example of flexible polymeric packaging is

Doypack bags (stand-up pouches) made of composite polymeric materials. They have a fold in their bottoms, which becomes wide flat when pouches are filled with a product, so that they can stand erect. These pouches are used to package liquid, pastelike, or flowable products (mayonnaise, ketchup, sour cream, condensed milk). Besides, this packaging is often filled with baby food. A stand-up pouch is made from two, three, or four layers of laminated film, 80–160  $\mu\text{m}$  thick. A three-layer film, for example, is interlayered with aluminium foil, which blocks light and moisture, thus being an important barrier between the content of the pouch and the environment, and allows extending the storage time up to one year. However, manufacturers try to use more technologically effective and cheaper alternatives to foil, like EVOH or multilayer barrier film consisting of PET/Al/Bonyl/PP, PP/Bonyl/PPP (PET for polyethylene terephthalate, Al for aluminium foil, Bonyl is a high-barrier polymer made by DuPont, PP for polypropylene, PPP for cast polypropylene). This composition of the material allows keeping containers in an autoclave for 30–60 min at 120–130°C. The shelf life of sterilised products kept in stand-up pouches is two years and more. The heat sterilisation methods used for this packaging type are hot filling, pasteurisation, sterilisation, aseptic packaging, combined method [11,12].

An interesting and promising packaging type is flexible polymeric retort pouches made from specific multilayer films. By their properties, these films must be neutral to food products, heat-sealable, nonshrinking, and resistant to temperatures as high as 121°C for as long as sterilisation can take. A container for sterilising in an autoclave is a flexible rectangular laminated package made from polymeric materials (aluminium foil laminated with layers of polymeric materials, or laminates based on polymeric films with no foil used), with four seams heat-sealed airtight. A product in this container can be heat-treated. This packaging is of high quality, light, durable, and easy to use. Products packaged in it are convenience food (first and second courses of a meal), pet food, and others, with a long shelf life of up to 2 years [13].

When using different types of containers to sterilise canned food and prevent physical defects in finished products, one should consider the technological features of cans, such as their closure strength or their depressurisation pressure. These features depend on the type of packaging, method of closure, diameter of a container's opening, absence or presence of a relief on the cover, temperature of packaging, and other factors. There is scientific evidence that closure strength increases with smaller diameters of a container's opening, or with the presence of a stiffness relief on the surface of the cover. If canned food is sterilised using polymeric containers made from heat-resistant barrier materials,

such parameters as closure strength or depressurisation pressure are of major importance: knowing their values, one can prevent physical damage to the cans [14,15].

The study is novel in that it has resulted in developing technological parameters, sterilisation modes for metal containers, with upper covers made of a flexible heat-resistant polymeric barrier material (PET/PE), and those for semi-rigid polymeric containers (PET/EVOH/PPP), with aluminium foil covers coated with a thermoplastic, for certain thermal processing equipment and for certain food products.

**The purpose** of the research was developing the right conditions for canning food in metal containers, with lids made of a flexible heat-resistant polymeric barrier material (PET/PE), and in semi-rigid polymeric containers (PET/EVOH/PPP), with aluminium foil covers coated with a thermoplastic, for certain thermal processing equipment and for certain food products. According to this purpose, the following research **objectives** were set:

- to determine the closure strength, or depressurising pressure, for metal containers, with lids made of a flexible heat-resistant polymeric barrier material (PET/PE), and for semi-rigid polymeric containers (PET/EVOH/PPP), with aluminium foil covers coated with a thermoplastic;
- to carry out thermophysical studies of the heating processes that take place in food packaged in the retail containers considered;
- to develop and implement the modes of sterilisation in a vertical autoclave B6-KAV-2 and in a horizontal static steriliser by Lagarde for canned smoked sprat in oil and canned meat pâté packaged in containers of the types under study.

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#### Research materials and methods

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Metal can No. 2, nominal volume 175.0  $\text{cm}^3$ , nominal outer diameter 103.0 mm, with a lid made from a flexible polymeric barrier material (PET/PE), manufactured by *OOO Mifrid*, Dnipro, Ukraine; semi-rigid polymeric container made from the multilayer barrier material PET/EVOH/PPP, with an aluminium foil cover coated with a thermoplastic, nominal volume 120.0  $\text{cm}^3$ , nominal outer diameter 85.0 mm, manufactured by *OOO Alfa Pak*, Kyiv, Ukraine. These types of containers are shown in Fig. 1 and 2.

The research was carried out at Odessa National Academy of Food Technologies, in the Food Sterilisation Laboratory.

The closure strength or the depressurising pressure (this pressure can develop due to the product's thermal expansion) was measured by the standard membrane-compensation method. The testing unit consisted of a surface plate and a lever-arm mechanical indicator. The functional diagram of the testing unit is shown in Fig. 3.



Fig. 1. Metal can with a lid made from the heat-resistant polymeric material PET/PE



Fig. 2. Semi-rigid polymeric containers made from the multilayer barrier material PET/EVOH/ CPP, with aluminium foil covers coated with a thermoplastic

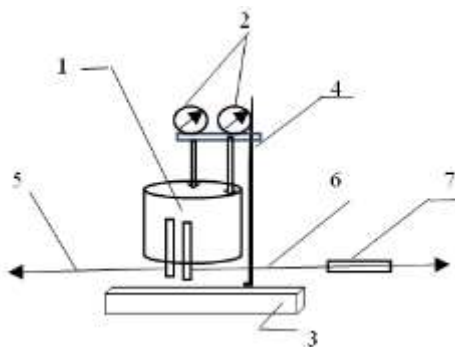


Fig. 3. Diagram of the testing unit to study the central sag of the cover and the container's closure strength  
1 – container; 2 – indicator; 3 – surface plate; 4 – membrane unit; 5 – air duct capillary tube; 6 – capillary tube to the membrane unit; 7 – clamp stand for the container

By means of the capillary tubes, a container is connected to the vacuum pump, and through the membrane unit, to the compensation line. The vacuum pump feeds air into the receiver, thus creating excessive pressure in the container. The pressure was measured using the membrane unit connected to the container. The deformation of the cover was measured with the mechanical lever-arm indicator, and the closure strength using a pressure gauge. The measurements were performed at intervals of 0.01 MPa. After the maximum sag value was reached, with the container remaining hermetic, the internal pressure was reduced to 0.1 MPa, and the indicator was used to determine whether there was any permanent residual deformation. The experiment was carried out under normal conditions (ambient temperature 18–20°C, atmospheric pressure 0.1 MPa). This assumption is possible, because within the range of the technological processing temperatures, there are practically no changes in the mechanical characteristics of a container [14,16]. The experiments were replicated 10 times. The findings have been processed using mathematical statistical methods.

The canned food sterilisation modes have been developed according to the standing regulations [16]. The procedure stipulated in the regulations includes analytical

calculation of a mode that allows industrially manufacturing sterilised canned food, and testing the selected mode in the laboratory and in a production environment. In the analytical calculation of sterilisation modes, the changes in the temperature of the product during sterilisation are taken into account. The calculation method that can be used in practice is based on the analytical comparison of whether the required lethality of a sterilisation mode is equivalent to the actual lethality in the point where the canned product is least heated during the thermal treatment. Any method of calculating the modes is based on the heat resistance parameters of the strain of the test culture microorganisms, since these parameters are supposed to ensure the manufacturing sterility of the canned food [18]. The sterilisation modes were developed for canned smoked sprat in oil and canned meat pâté. The studies were repeated in triplicate. The findings were processed using mathematical statistical methods [19].

### Results of the research and their discussion

A series of experiments have been conducted to determine the closure strength of the packaging types under study (metal can No. 2, volume 175.0 cm<sup>3</sup>, outer diameter 103.0 mm, with a lid made from the flexible polymeric barrier material PET/PE; semi-rigid polymeric container made from the multilayer barrier material PET/EVOH/ CPP, with an aluminium foil cover coated with a thermoplastic, volume 120.0 cm<sup>3</sup>, outer diameter 85.0 mm). The replications of the experiments are indicated in the description of the test unit. The research results are presented in Fig. 4 and 5.

The experimental data presented in Fig. 4 and 5 have shown that the closure strength of the metal and polymeric containers is 0.09 MPa, and the maximum sag in the centre of the can's upper covers is 1.15 mm, with no residual deformation of the cover. At a pressure above 0.09 MPa, containers become depressurised.

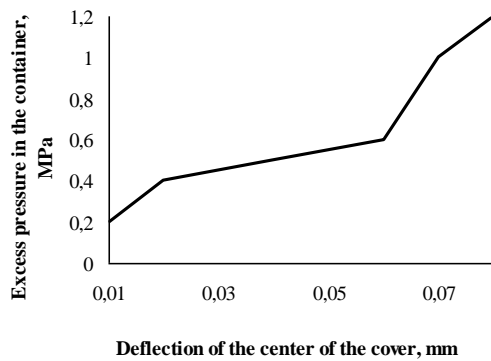


Fig. 4. Dependence of the central sag of the lid on the excessive pressure in metal containers with PET/PE lids

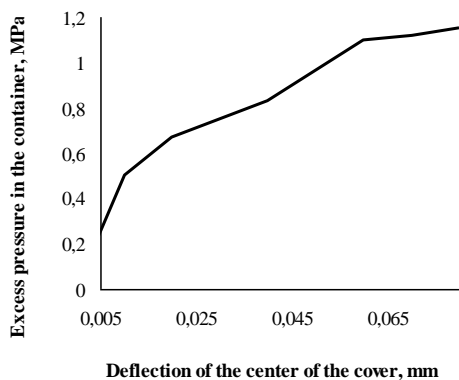


Fig. 5. Dependence of the central sag of the cover on the excessive pressure in semi-rigid PET/EVOH/PPP containers with aluminium foil covers

That is why, for heat sterilisation of food in the packaging of these types, the cooling conditions must be calculated so that the difference in pressure in the equipment and inside the can remains below a certain value established experimentally. Otherwise, the sealing of the containers will fail and the product will become defective.

Here is a calculation of excessive pressure in the types of containers under study that develops inside a hermetic can during heat treatment of meat pâté. In the course of thermal sterilisation of the container, there must be no mechanical loading on the cover, so that the calculated pressure inside the container corresponds to that in the sterilisation equipment [14,19].

During sterilisation in an enclosed unit, the excessive internal pressure in the containers under study is equal to the initial partial pressure of air at the moment when the cans are sealed hermetically. It is calculated by the formula:

$$P_e = P_i = 0.1 - P_p \quad (1)$$

where 0.1 is the atmospheric pressure of the air in the container being hermetically sealed, MPa,

$P_p$  is the partial pressure of water vapour in the container being hermetically sealed (the function of the temperature at which a product is packaged, °C), MPa.

$$P_e = 0.1 - 0.0023 = 0.09 \text{ MPa} \quad (2)$$

During sterilisation, the experimental and the calculated excessive internal pressures in the containers studied are the same, equal to 0.09 MPa [14].

Analysis of the experimental and the calculated data obtained has shown that both types of packaging can withstand the maximum excessive internal pressure 0.9 kgf/cm<sup>2</sup> (0.09 MPa). Higher values result in complete depressurisation. Therefore, during the technological operations, the maximum pressure in the containers with canned food must not exceed this limit.

When the food packaged in the containers under study (meat and fish pâtés, fish products) is heat-treated, the modes of cooling the finished products must be calculated so that the difference in pressure in the equipment and inside the can with the product remains below the experimentally established value [14,19].

Besides, the following modes have been developed for heat treatment of food in these types of containers [14,17,18].

1. Heat treatment of canned smoked sprats in oil in an autoclave B6-KAV-2 [14, 18], with the product put into a 175 cm<sup>3</sup> metal container No.2 with a heat-resistant PET/PE lid. The parameters obtained are presented in Table 1. Sterilisation mode:

$$\frac{15-40-25}{(120 \pm 1) \text{ } ^\circ\text{C}} (0.180 \pm 0.10) \text{ MPa} \quad (3)$$

When developing this sterilisation mode, the following parameters of the process in the autoclave were determined: sterilisation temperature 120±1°C, time of heating the autoclave up to the sterilisation temperature 15 min, actual sterilisation time 40 min, time of cooling the autoclave down 25 min. These microbiological parameters are supposed to provide the industrial sterility of canned food. The maximum pressure in the autoclave 0.180±0.10 MPa and the tabulated values of pressure will help prevent physical defects of cans.

2. Heat treatment of canned meat pâté in a horizontal static autoclave Lagarde [18], with the product placed into a 103 cm<sup>3</sup> semi-rigid polymeric container made from the multilayer barrier material PET/EVOH/PPP, with an aluminium foil cover coated with a thermoplastic. The parameters obtained are presented in Table 2.

$$\frac{7-50-34}{(121 \pm 1) \text{ } ^\circ\text{C}} \cdot 0.210 \text{ MPa} \quad (4)$$

When developing this sterilisation mode, the following parameters of the process in the autoclave were determined: sterilisation temperature 120±1°C, time of heating the autoclave up to the sterilisation temperature 7 min, actual sterilisation time 50 min, time of cooling the autoclave down 34 min. These microbiological parameters are supposed to provide the industrial sterility of canned food. The maximum pressure in the autoclave 0.180±0.10 MPa and the tabulated values of pressure will help prevent physical defects of cans.

**Table 1 – Parameters of the process of sterilising canned smoked sprats in oil in an autoclave B6-KAV-2 using a metal container No. 2**

Time, min	Temperature of water in the autoclave, °C	Pressure in the autoclave, MPa
0	40	0
5	70	0.060
10	100	0.130
15	120	0.175
20	120	0.180
25		
30		
35		
40		
45		
50		
55	100	0.175
60		
65	80	0.130
70	60	0.100
75	50	0.080
80	40	0.01

**Table 2 – Parameters of the process of sterilising canned meat pâté in a Lagarde autoclave using a 103 cm<sup>3</sup> semi-rigid polymer container made from PET/EVOH/PPP**

Time, min	Temperature of water in the autoclave, °C	Pressure in the autoclave, MPa
0	40	0
5	70	0.060
10	100	0.130
15	120	0.175
20	120	0.180
25		
30		
35		
40		
45		
50		
55	100	0.175
60		
65	80	0.130
70	60	0.100
75	50	0.080
80	40	0.01

**Field testing of the research results.** The topic of the research was determined by an economic contract between Odessa National Academy of Food Technologies and the enterprises:

– LLC *Khodoriv Meat Packing Factory*, Lviv Region, Ukraine (semi-rigid polymeric container made from the multilayer barrier material PET/EVOH/PPP, with an aluminium foil cover coated with a thermoplastic);

– JSC *Busk Cannery*, Lviv Region, Ukraine (175 cm<sup>3</sup> metal container No. 2 with a heat-resistant PET/PE lid).

Thus, the research findings have been implemented at these enterprises.

### Conclusion

When the metal and polymeric containers considered in this research are used to sterilise food in autoclaves, it is important to start lowering the pressure at the cooling stage at a temperature not higher than 85°C. At all the stages of heat treatment, the difference between the pressure in the autoclave and that in the can with food must be maintained not higher than 0.09 MPa to provide the proper mechanical condition of the product. Under these conditions, there must be no loading on the upper cover to prevent seal failure and depressurisation of the can.

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## КОНСЕРВУВАННЯ ХАРЧОВИХ ПРОДУКТІВ У НАПІВЖОРСТКІЙ ПОЛІМЕРНІЙ І КОМБІНОВАНІЙ ТАРІ

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**Анотація.** Для теплового консервування харчових продуктів може використовуватися споживча полімерна тара різних типів: жорстка, напівжорстка, м'яка та інші. Щоб пластикова (полімерна) упаковка могла застосовуватися для теплової стерилізації і гарантувати тривалі терміни зберігання харчових продуктів, вона повинна містити необхідний бар'єрний термостійкий шар, який забезпечить стійкість тари до високих температур, запобігатиме потраплянню кисню і збереже якість і харчову цінність продукту. Кожен полімерний матеріал має певні показники термостійкості. В роботі використовувалися такі види споживчої упаковки для фасування харчових продуктів, як комбінована металева банка з полімерною кришкою і полімерна напівжорстка тара з термостійкого матеріалу з кришкою з фольги. При використанні різних видів тари для теплової стерилізації і запобігання фізичного браку консервів необхідно враховувати такі технологічні особливості банок, як міцність закупорювання або тиск розгерметизації, спосіб закупорювання, діаметр горловини тари, наявність або відсутність рельєфу жорсткості на кришці, температуру фасування продукту й інші фактори. В роботі проведено аналіз існуючих видів комбінованої, полімерної споживчої тари, яка застосовується для консервування харчових продуктів різними способами теплової стерилізації. Проведено теоретичні та експериментальні дослідження, в результаті яких отримано показники важливого технологічного параметра тари – міцність закупорювання, без значень якого неможливо провести якісну теплову стерилізацію продукту; розроблені науково обґрунтовані параметри, режими високотемпературної стерилізації для м'ясних і рибних продуктів в комбінованій металевій і полімерній напівжорсткій термостійкій тарі, що дозволить підприємствам випустити консервовані якісні продукти харчування безпечно у використанні, з високою харчовою цінністю.

**Ключові слова:** стерилізація, технологічні параметри, тара, міцність закупорювання, тиск розгерметизації.

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