

High-temperature multilevel sterilization of canned goods with heat recovery and its constructive and technological support

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Abstract. New technical solutions improving the process of thermal sterilization of canned products through the use of multilevel high-temperature modes and heat recovery have been considered and proposed. The essence of the developed method lies in the fact that the heat released by cooling cans with the product that has undergone thermal sterilization is used to heat other cans with the product queued for sterilization. In this mode of heat treatment, except in the last stage, the heat emitted by cooled cans that have already undergone heat treatment is used to heat up the canned food. Hence, the use of the principle of heat recovery by cooling canned products in the baths where others are simultaneously heated provides a significant saving of heat energy and water. Depending on the temperature parameters at different stages of the heat treatment, the heat recovery rate can reach up to 90%. The method also provides savings on cooling water. For the practical implementation of the developed method, the design of the device for multilevel high-temperature thermal sterilization of canned food with heat recovery has been developed. On the basis of experimental studies, new, multilevel high-temperature modes of apple compote sterilization have been developed.

1 Introduction

The noncompetitiveness of agroindustrial complex (AIC) processing enterprises, including those producing canned food, is largely based on the inefficiency of energy consumption. Their progressive development is impossible without the introduction of energy-efficient and high-tech production processes and equipment. Primarily, the solution to this problem lies in the development of energy-saving technologies and technologically cost-effective processes and equipment.

AIC enterprises processing raw materials are now searching for energy-saving solutions and technologies that can provide a quick and tangible effect, as reducing energy costs is an effective mechanism for improving the competitiveness of products.

The issues of energy efficiency are now being addressed by the Russian state authorities, which is reflected in the order of the Russian Government of November 13, 2009 No.1715-R "Russia's Energy Strategy for the period up to 2030."

The main, mandatory and final stage, and also the most energy-intensive, in the technological cycle of processing agricultural raw materials into canned foods is the process of sterilization [1-6, 9-11]. This process is used in the production of all long-term storage products in hermetically sealed containers.

There are a large number of methods and equipment for thermal sterilization, which differ in their efficiency,

energy costs and applicability for sterilization of canned products of different types [4-6].

Thermal evaluation of the technological cycle of canned food production shows that the most energy intensive process in it is the process of sterilization, and the development of new energy-saving methods and devices for its realization is a pressing problem of food technology. Intensification and increasing the efficiency of sterilization equipment while ensuring high quality of canned products are the main goals set by developers during modernization of traditional and development of new methods and devices for thermal sterilization. Which is why the research of new methods and equipment for efficient thermal sterilization is a very topical problem of practical interest to the AIC enterprises.

2 Goals and objectives

The goal of the research is to develop a resource-saving method, mode of its implementation, and the design of an open-type equipment for high-temperature multilevel sterilization of canned food using liquid high-temperature heat carriers and heat recovery.

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Table 1. Multilevel high-temperature sterilization modes.

Canned product name	Volume of jars, l	Duration of traditional modes, min	Multilevel thermal sterilization modes with heat recovery
Apple compote	1.0	85	$\left(\frac{6}{60} \cdot \frac{6}{80} \cdot \frac{6}{100} \cdot \frac{6}{110}\right) \cdot \left(\frac{6}{80} \cdot \frac{6}{60} \cdot \frac{6}{40}\right) \cdot 0.2$
	0.5	65	$\left(\frac{4}{60} \cdot \frac{4}{80} \cdot \frac{4}{100} \cdot \frac{4}{110}\right) \cdot \left(\frac{4}{80} \cdot \frac{4}{60} \cdot \frac{4}{40}\right) \cdot 0.15$

by the driver through the driving sprocket 13.

The device operates in the following manner. Gall’s chains 6 together with fixed carriers for glass jars make intermittent progressive movement, moving from bath to bath. They start with the second one, alongside sterilized jars secured in carriers, then proceed into the third, fourth and fifth baths on the upper branch of the transporting organ and further onto the lower branch returning to the fourth, third, second and first for final cooling. At the same time, the supply of cans into the carriers 11 is carried out during the stops of the transporting organ. The jars installed into carriers ensuring their mechanical hermitization sequentially pass the second, third, fourth and fifth baths for successive heating. In the second, third, and fourth baths, the jars supplied on the top branch are heated through the cooling of glass jars with the product supplied on the lower branch of the transporter into these very baths. The fifth bath with high-temperature heat carrier is only used for heating, and in the first bath with water at 40 °C, the final cooling is carried out. The heat carrier temperatures in the baths are automatically supported at, respectively, 40 °C, 60 °C, 80 °C, 100 °C, and 120 °C. The proposed design solution, with the movement of cooled cans in the bottom row and heated ones in the upper, also contributes to the natural circulation of the heat carrier in the baths.

The heat consumption in the unit takes place only in the fifth bath for heating canned food from 92–95 °C to 100 °C (for acidic canned foods, sterilized at 100 °C) and up to 115–118 °C (for non-acidic canned food, sterilized at temperatures of 116–120 °C), as well as to compensate for environmental losses, and water is consumed only in the first bath for cooling canned food from 60–65 °C to 40 °C.

The savings in heat energy and water compared to the periodic-action devices used in the industry (autoclaves) are over 90%.

The increase in the recovery rate can be achieved by changing the temperature parameters of the heating of canned food in the penultimate bath for heating. The higher this temperature, the greater the recovery factor. When the method is implemented in practice, the coefficient reaches up to 0.90.

On the basis of experimental studies on warming dynamics of apple compote in different containers, new multilevel high-temperature rotational sterilization modes have been developed [11-18] (Table1).

The formulas of multilevel sterilization modes in the numerator indicate the duration of the heat treatment in minutes, and in the denominator they contain the temperature levels of the coolant at each stage of the

thermal treatment in °C and the frequency of rotation of the glass cans in s⁻¹.

5 Conclusion

A new way of multilevel high-temperature thermal sterilization of canned food with heat recovery and rotation of glassware has been developed. High-temperature multilevel thermal sterilization modes for apple compote in various containers, the duration of which is more than 50% less than that of the modes of traditional technology have been established. Moreover, it provides for saving in excess of 90% of heat energy due to its reuse.

The technical solutions presented can be recommended for use in AIC enterprises as providing high quality and safety of products and resource conservation.

References

1. M.E. Akhmedov, A.F. Demirova, G.I. Kasyanov, A.M. Darbisheva, T.N. Daudova, L.A. Daudova, Russian Agricultural Sciences, **42 (1)**, 113-116 (2016)
2. G. Kasyanov, T. Davydenko, Food Science and Technology, **11 (1)**, 75-78 (2017)
3. K. Sakibaev, L. Pylypenko, T. Nikitchina, G. Kasyanov, Food Science and Technology, **13 (2)**, 128-135 (2019)
4. A.F. Demirova, M.E. Akhmedov, M.M. Alibekova, T.N. Daudova, M.M. Omarov, Z.A. Abdulkhalikov, Russian Agricultural Science, **4**, 61-64 (2018)
5. M.D. Mukailov, N.A. Ulchibekova, T.A. Isrigova, M.E. Akhmedov, U.A. Selimova, International Journal of Advanced Science and Technology, **29 (9s)**, 1167-1172 (2020)
6. M. Akhmedov, A. Demirova, V. Piniaskin, R.A. Rakhmanova, E3S Web of Conferences, **161 (1)**, 01056 (2020)
7. M. Akhmedov, A. Demirova, Z. Abdulkhalikov, T. Daudova, L. Daudova, E3S Web of Conferences, **161** (2020)
8. V. Derevenko, G. Kasyanov, L. Pylypenko, Food Science and Technology, **12 (2)**, 39-45 (2018)
9. M. Aider, E. Olkhovtov, L. Pylypenko, T. Nikitchina, G. Kasyanov, Food Science and Technology, **12 (4)**, 63-71 (2018)

10. T.A. Ismayilov, A.F. Demirova, M.E. Akhmedov, M.M. Akhmedova, *A device for high-temperature thermal sterilization of canned products* (Pat. RF no. 2604919, bull. no. 35, 20.12.2016)
11. Collection of technological instructions for the production of canned goods, Moscow, **2**, 355 (1977)
12. B.L. Flaumenbaum, S.S. Tanchev, M.A. Grishin, *Basics of food sterilization* (Agropromizdat, Moscow, 1986, 264)
13. V.P. Babarin, *Sterilization of canned food* (GIORD, St. Petersburg, 2006, 312)
14. G.I. Kasyanov, A.F. Demirova, M.E. Akhmedov, Reports of the Russian Academy of Agricultural Sciences, **6**, 57-59 (2014)
15. G.I. Kasyanov, Bulletin of Universities, Food Technology, **1**, 35-38 (2014)
16. O.R. Panina, G.I. Kasyanov, S.V. Rohman, Bulletin of Universities, Food Technology, **1**, 122-124 (2014)
17. M.E. Akhmedov, N.G. Zagirov, A.F. Demirov, M.M. Akhmedova, R.A. Rakhmanova, *Equipment for heating fruits and vegetables in jars* (Pat. RF no. 2666371, 07.09.2018)
18. Guide on the development of sterilization and pasteurization regimes for canned products (GNU VNIICOP, 2011)