Comparative analysis of temperature loggers used in the development of regimes for heat treatment of food production in autoclaves

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Abstract. Heat treatment processes carried out in an autoclave at a temperature from 60 up to 130 °C are usually applied in the canned food production. Actual process lethality value is used as a criterion determining the product readiness and its microbiological safety. It is computed by summing the lethal effect values of heating obtained at different temperatures recorded inside the tin can with product. Loggers (thermographs) are special technical means of temperature measurement and recording in an electronic storage device, used to automate the task of obtaining product temperature kinetics. The article provides a comparative analysis of the widespread Thermochron DS1922T (used in the Thermochron protector capsule) and Ellab TrackSense PRO loggers, which protection class allows working in conditions (water, high temperatures and pressure) specific for typical heat treatment product regime. The logger Ellab TrackSense PRO was accepted as an etalon. Loggers recorded the temperature at the least heated point of the autoclave sterilization chamber during all processes. The graphs of temperature kinetics for pasteurization and sterilization processes were received in series of experiments. Thermochron thermographs absolute and relative errors, declared by the manufacturer, are experimentally verified. In result, the conclusion and recommendations of thermal recorder Thermochron DS1922T utilization are given.

1. Introduction
In the canned food production heat treatment processes, like sterilization or pasteurization, are applied. These processes are usually carried out in an autoclave at a temperature from 60 up to 130 °C, depending on the heat treatment regime selection.

As a criterion determining the product readiness and its microbiological safety, the actual process lethality value (F-effect for pasteurization or Pasteur criterion for pasteurization) is used. It takes into account the basic temperature of the heat treatment process.

The actual lethality value calculation is computed by summing the lethal effect values of heating obtained at different temperatures recorded during the process inside the product [1]. It is necessary to use special technical means of measuring and temperature recording to automate the task of obtaining product temperature kinetics.

2. Objects and materials
Widespread means of temperature recording are loggers (thermographs), which record measurement results in an electronic storage device for long-term storage and post processing. However, almost all
thermal loggers do not have the required protection class to work in water, at high temperatures and pressures, determined by the heat treatment product regime.

So it is possible to formulate the challenge of choosing the appropriate technical means of measuring and temperature recording for quality control and microbiological safety of the end-product.

In the Russian and foreign marketplaces, suitable for above conditions devices are Thermochron thermograms (iButton DS1922T series) of the scientific and technical laboratory «Electronic Instruments» and Ellab TrackSense PRO complex loggers (Figure 1). The main characteristics of these loggers are presented in table 1.

| Characteristic | Thermochron DS1922T (iBDL-T) | Ellab TrackSense PRO |
|---------------|-----------------------------|----------------------|
| Temperature range, °C | from 0 to +125 | from -30 to +150 |
| Accuracy, °C | 0,5 (8-bit data) or 0,0625 (16-bit data) | ±0,05 |
| Error, °C | from 20 to 75 °C: not more than ±0,5 | ±0,05 |
| from 75 to 125 °C: not more than ±2,0 | |
| Error of the built-in clock, minutes per month | ±2,0 | ±2,5 |
| Battery life | up to 9 years (temperature up to +50 °C, 8-bit data, measurement period more than 5 minutes) | up to 12 months (at temperature +121 °C, measurement period 15 seconds) |
| Degree of protection | IP56 | IP68 |
| Operating pressure, bar | – | up to 10 bar |
| Dimensions, mm | diameter – 17,3 | diameter – 25 |
| | thickness – 5,9 | height – 45 |
| Weight, g | 3,3 | 48 |
| Memory capacity | 8192 measurements | 60000 records |
| Software | iBDL_R | ValSuite |
| Communication interfaces | 1-Wire (logger - iBDL complex), USB (iBDL complex - computer) | radio frequency channel (logger - read station), USB (read station - computer) |
| Additional equipment | Thermochron capsule protector (pressure up to 10 atm), iBDL measuring complex, DS9107 capsule made of PPS plastic | Main reading station TrackSense PRO |
3. Experiment description

As part of this study, a comparative analysis of two temperature loggers, used in the process of food products pasteurization and sterilization in the water environment, has been carried out.

Pasteurization of the product from hydrobionts in the tin can #2 was conducted in the AVK-30M laboratory autoclave [2]. It is a modernized sterilizer with an automatic control system developed at the Automation and Computer Engineering Department of the Murmansk State Technical University. Pasteurization regime 10–60–20 minutes (heating stage – pasteurization process – cooling stage) at temperatures 80, 85 and 95 °C was chosen for research.

Sterilization processes of canned food "Murmansk cod liver" in the tin can 1K were performed in an industrial autoclave ASCAMAT-230 manufactured by ASCA GmbH (Germany) [2]. The canned food sterilization regime 35-30-20 minutes (heating stage – sterilization process – cooling stage) with back pressure at a temperature approximately 120 °C was chosen.

During all experiments, two types of loggers (Thermochron iButton DS1922T series and Ellab TrackSense PRO) were used to record the temperature at the least heated point of the autoclave sterilization chamber. The temperature inside cans was recorded by the Ellab TrackSense PRO loggers at the point with the lowest heating temperature of the product.

4. Results and discussion

The graphs of temperature kinetics in autoclave’s sterilization chamber for pasteurization and sterilization processes were received in series of experiments. Also the graphs of Thermochron DS1922T absolute errors shown on figures 2–9 were received. The logger Ellab TrackSense PRO was accepted as an etalon, because it had more accurate metrological specifications presented in table 1.

Following notation is accepted on figures 2, 4, 6, 8: red solid line – temperature in autoclave’s sterilization chamber measured by Thermochron; blue medium dash line – temperature in autoclave’s sterilization chamber measured by Ellab; green long dash line – product temperature kinetic measured in the minimum warmed point in can by Ellab logger.

Graphs of Thermochron DS1922T absolute errors shown on figures 3, 5, 7, 9 without consideration of heating and cooling stages of thermographs due to differences in the recorder heating dynamics (the Thermochron DS1922T logger is used in the Thermochron protector capsule).

The calculated values of the Thermochron iButton DS1922T temperature errors obtained during pasteurization and sterilization processes are summarized in Table 2.
Figure 2. Graphs of temperature kinetics for sterilization process #1.

Figure 3. Graph of Thermochron DS1922T absolute errors for sterilization processes #1.
Figure 4. Graphs of temperature kinetics for sterilization process #2.

Figure 5. Graph of Thermochron DS1922T absolute errors for sterilization processes #2.
Figure 6. Graphs of temperature kinetics for pasteurization process #1.

Figure 7. Graphs of temperature kinetics for pasteurization process #2.
Figure 8. Graphs of temperature kinetics for pasteurization process #3.

According to the table 2 the maximum temperature measurement deviation of Thermochron thermographs from the Ellab loggers during the experiments is no more than 1.2 °C. At the same time, the average absolute error is not more than 0.6 °C, the average relative error is not more than 0.75 percent.

Figure 9. Graphs of Thermochron DS1922T absolute errors for pasteurization processes.
Table 2. Temperature measurement errors of Thermochron thermograph.

| Technological process regime | Minimum absolute error, °C | Maximum absolute error, °C | Average absolute error, °C | Average relative error, % |
|------------------------------|---------------------------|----------------------------|--------------------------|--------------------------|
| Sterilization                |                           |                            |                          |                          |
| Process #1 (35-30-20 at T = 118 °C) | 0                         | 1.2                        | 0.59                     | 0.5                      |
| Process #2 (35-30-20 at T = 118 °C) | 0                         | 0.94                       | 0.33                     | 0.3                      |
| Pasteurization               |                           |                            |                          |                          |
| Process #1 (10-60-20 at T = 80 °C) | 0                         | 0.87                       | 0.34                     | 0.43                     |
| Process #2 (10-60-20 at T = 85 °C) | 0                         | 1.05                       | 0.46                     | 0.58                     |
| Process #3 (10-60-20 at T = 95 °C) | 0                         | 0.82                       | 0.58                     | 0.74                     |

5. Conclusion and recommendations

In conclusion, we can mark the following items:

- absolute measurement error of Thermochron DS1922T, declared by the manufacturer (not more than 2.0 °C), was confirmed experimentally (not more than 1.2 °C) when measuring the temperature during pasteurization and sterilization processes;
- Thermochron DS1922T specifications meet the requirements for means of temperature measurement during the heat treatment process of products in an autoclave.

Therefore, we can offer the following recommendations for using Thermochron thermographs:

- use of Thermochron DS1922T loggers will reduce the cost of developing a product heat treatment regime, because the cost of equipment set (recorders, reading station, software) less than that of Ellab TrackSense PRO;
- Thermochron thermometers for measuring temperature in the aquatic environment during the sterilization process should be placed in a Thermochron protector capsule against overpressure.

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