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DEVELOPMENT OF AN ENERGY-SAVING TECHNOLOGICAL SYSTEM TO IMPROVE THE HEAT TREATMENT STAGE OF MILK

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Abstract: In order to meet the demand of the population for agricultural products, the products are stored and processed. Part of the processing of milk and milk products is pasteurization. In this article, detailed information is provided about the thermal calculation of pasteurizer plates for heat treatment of dairy products, its improvement and energy-saving technological system. Plate pasteurizers used in large milk processing enterprises consist of several sections, raw milk is first heated in its raw state for separation, and then directed to homogenization. After homogenization, it returns to the pasteurizer and is heated and pasteurized at the required temperature in the heating section. But in small milk processing enterprises, separation and homogenization are carried out separately, since such a complex system is expensive and requires a lot of energy. therefore, the sections of the plate pasteurizer consist of 3 types of cooling, recuperation and heating, and adjusting the output temperature of milk causes some difficulties. In this article, the problem of improvement of pasteurizer with plates used in small-scale milk processing enterprises is highlighted.

Keywords: pasteurizer, plate, thermal balance, fermentation, recuperation, water, milk.

Introduction. From ancient times to the present day, the demand for dairy products is increasing year by year. Because dairy products have a positive effect on the human body and actively participate in metabolism. According to the statistics provided by the Organization for Economic Cooperation and Development (OECD), the volume of world milk production is expected to grow by 1.6% per year. During the forecast period, it is expected to grow to 997 million tons by 2029, faster than other main agricultural products [1]. In this regard, the processing of milk and dairy products is one of the urgent tasks of today.

According to data, in 2022, the volume of milk production in Uzbekistan was 11,009.9 thousand tons, and the annual consumption of milk and milk products was about 16% of all types of food products [2].

In the world, processing of milk and milk products, their processing and a lot of scientific research, experiments and research are being conducted on them. In particular, in the leading scientific centers of Europe, the properties of dairy products, changes in their processing, and their processing and processing technologies are being improved. With the increase of modern knowledge, new techniques and technologies are being applied to our life, new types of products and new methods of their creation are being invented. From this point of view, we can say that the relevance of the article topic is important based on the demand for milk and milk products, their sanitary and hygienic condition.

Methodology. A plate pasteurizer produced in Poland in 2005, capable of pasteurizing 300 liters of milk per hour, was selected as an experimental device. The holding section of the experimental device is located between the plates, and in our initial experiments, a zig-zag type holding pipe was installed on the device [3]. A holding pipe is basically a container or pipe in which a heated liquid product (for example, milk or juice) is kept at a certain temperature for a predetermined time. The combination of time and temperature is critical to effectively kill any harmful bacteria and pathogens that may be present.

Ensures complete inactivation of pathogens: heating kills most bacteria, some heat-resistant bacteria require constant exposure to high temperatures to kill. The holding pipeline guarantees this dwell time for complete inactivation.

Many countries have strict regulations for pasteurization temperatures and storage times. The containment pipe ensures that the product meets these requirements for safe consumption. Maintaining the correct temperature and storage time helps maintain product quality and flavor by minimizing heat damage and over-processing. The holding tube is usually designed with a zig-zag configuration to increase product life while maintaining a compact size. Temperature sensors and flow meters are usually installed at the outlet of the holding pipe to effectively monitor and control the process[4].

In some plate pasteurizers, the retention section may be integrated into the plate heat exchanger itself, eliminating the need for a separate retention tube[5].

Figure 1.1. Plate pasteurizer.

1-cooling section; 2-recuperation; 3-heating section; 4- operating panel; 5-water heating tank; 6- inter plate holding section; 7- balance tank

Figure 1.2. Measuring chemical components and pH of milk.

Results.

Table 1. Chemical composition of milk.

№	A	B
1	Fat content	4-4.4 %
2	SNF	8.9-9.7 %
3	Density	1027-1030 g/ml
4	Freezing point	0.512-0.560 ºC
5	Protein	3.20-3.60 g
6	Lactose	5-5.5
7	Mineral salts	0.5-0.8
8	pH	6.72

To adjust the output temperature of the milk, we have installed a 3-way thermostatic valve combining the holding pipe and the output pipe, and the valve will automatically adjust the temperature we need. During the experimental tests, taking milk from the hot milk flow through the holding pipe was insufficient to heat the milk coming from the balance tank, which was the second flow of the recuperation part. This is because the amount of hot milk consumed is reduced. Due to this, the temperature of the heating water in the heating department was not suddenly reduced, but as a result, the pasteurization temperature dropped to 62-64ºC. Water heaters in the water heating block were continuous works with the help of automatic on-off switches before adding to the device construction. By ensuring continuous operation of water heaters, it was possible to increase the temperature of hot water to 76-78ºC, but the required temperature of 88ºC was not provided to us. Therefore, we added another 2 kW heater and brought the temperature to 88ºC and this temperature was continuously maintained. The technological scheme of the pasteurizer equipped with a 3-way valve is depicted in Figure 1.3

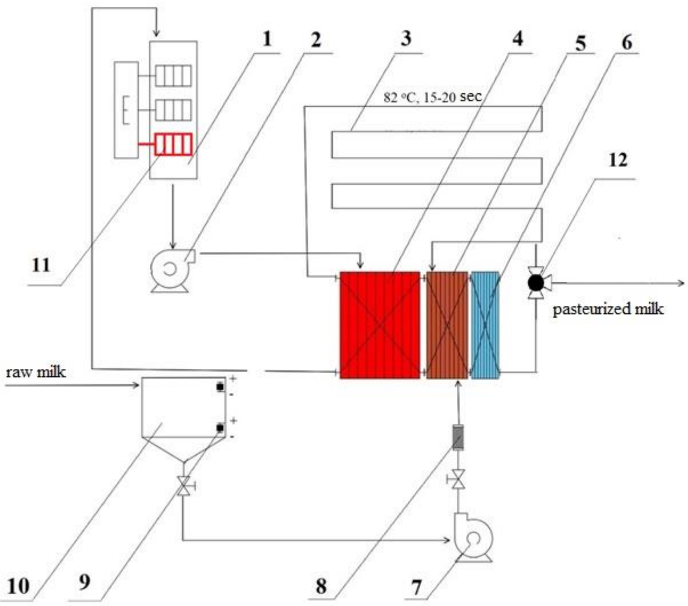


Figure 1.3. Technological drawing of an improved plate pasteurizer

1-water heating tank; 2-water circulation pump; 3-holding pipe; 4-heating section of the heat exchanger; 5-recuperation section of the heat exchanger; 6-cooling section of the heat exchanger; 7-milk pump; 8-milk filter; 9 - balance tank shields; 10-balance tank; 11- additional installed water heater; 12- 3-way thermo-regulating valve.

Heat balance calculations of the improved pasteurizer were performed as follows.

Parameters of cold agent, (milk)

Consumption G_1, kg/s………………………………………………….0.083

Temperature, °C

input t_{1start}……………………………………………...…62

exit t_{1end}…………………...………………………………82

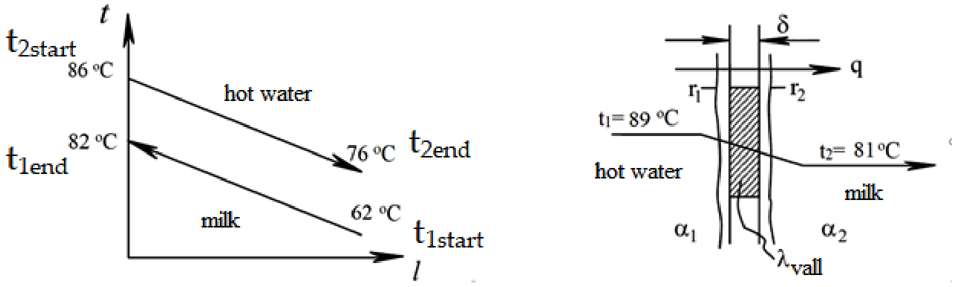
Parameters of the heating agent (hot water)

Temperature, °C

input t2start………………………………………………….86

exit t2end…………………...……………………………….76

The flow of the heat exchanger is opposite, and the following diagram shows the temperature change and the heat exchange process.



Average water temperature difference t_2, °C:

$$t_2=0.5(t_{2start}+t_{2end}) = 0.5(86+76) = 81\ °C \quad (1.1)$$

$$\Delta t_{avg} = \frac{\Delta t_{big}-\Delta t_{small}}{\ln(\Delta t_{big}/\Delta t_{small})} = \frac{(86-82)-(76-62)}{\ln(4/14)} = 8\ °C \quad (1.2)$$

Average temperature difference of milk:

$$t_1=t_2+\Delta_{to`rt}= 81+8 = 89\ °C \quad (1.3)$$

Thermal-physical properties of milk (at 89 °C):

Density…………………………………………………………………… ϱ_1= 995 kg/m³
Thermal conductivity……………………………………………………… λ_1=0.619 W/(m•K)
Heat capacity………………………………………………………………. c_1= 3980 J/(kg·K)
Dynamic viscosity………………………………………………………… μ_1=0.550•10⁻³ Pa•s

Thermal-physical properties of water (at 81 °C):

Density ……………………………………………………………….. ϱ_1= 972 kg/m³
Thermal conductivity …………………………………………………..... λ_1=0.674 W/(m•K)
Heat capacity ……………………………………………………………. c_1= 4195 J/(kg·K)
Dynamic viscosity ……………………………………………………… μ_1=0.355•10⁻³ Pa•s

Heat load Q, W:

$$Q=G_1c_1\ (t_{1start}-t_{1end}) =0.083\cdot 4000\cdot (82-62) =6607\ VT \quad (1.4)$$

$$G_2 = \frac{Q}{C_2*(t_{2start}-t_{2end})} = \frac{6607}{4195*(86-76)} = 0.157 kg/s \quad (1.5)$$

The necessary consumption of hot water is 0.157 kg/s, which means almost 2 times more than the consumption of milk. In order to double the water consumption, the hot water circulation pump can be increased to 2 levels or, if necessary, up to 3 levels. The heat exchanger is equipped with a 1-2-3 level circulation pump from the manufacturer.

Conclusions. In summary, the holding tube is an important component of the plate pasteurizer, ensuring the safety and quality of the pasteurized product by providing the necessary holding time at the desired temperature for effective pathogen inactivation. We believe that the plate pasteurizer equipped with a 3-way valve is suitable for use in small-scale milk processing enterprises. Through the 3-way thermo regulator automatic valve, the output temperature can be adjusted by increasing the hot water consumption of the plate pasteurizer. By adjusting the output temperature, the separation period and the production time are reduced. as a result, energy savings are achieved.

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