Returning heat flow during thermal treatment of food

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Abstract

Introduction. Adaptation of newest thermophysical measuring devices permit to receive a new information concerning to technological processes, so permit to use sparingly of energy and raw materials.

Materials and methods. Highly sensitive and fast-response compact heat meter – disc diameter of 20 mm and a thickness of 1,2 mm – was used during study of hard cheese ripening. The temperature of air in camera was 10±0,25°C in accordance with regulations.

Results and discussion. Result of direct measurement of heat flux with heat meter, which was mounted at the top center surface of the piece of a green cheese is unexpected: near 30 % of the heat which is released in the cheese and discharging with the cooling air is returned to the cheese.Return of heat to cheese is a ballast load for the chiller of ripening cheese chamber. Its elimination or minimization is a source of energy and resources saving. The fact that the return (inverse) of the heat flow in the refrigeration of food processing was not known in the world of science. Ballast heat fluxes can occur in the heat treatment of food products, for example, during stabilization of the surface layer of cooked sausages with oscillating infrared roasting. Inversion heat flow occurs when the heat meter is on the opposite side (in shadow) of the transmitter. The selection of the coagulation time and the voltage on the emitter managed to reduce ballast heat flux in the central layers to one-third and the inverse flow of these layers - to zero. The maximum heat flux (and with it the total energy consumption) is reduced by 15-20 %. The cooling process is necessary to make special arrangements. Reducing the temperature control range during refrigerating treatment would reduce the amount of heat ballast, but would be reduced in proportion and amount of heat withdrawn per cycle "on-off". Reduced cycle time would lead to more rapid wear of chiller parts. If is not possible, you need to install a thermostatic switch as far as possible from the chilled goods.

Conclusion. Established fact that the possibility of ballast heat flows - one more argument in favor of a change to absorption chillers with heat recovery, the potential of which is large enough for any food enterprises, including dairy and cheese factory.

Introduction

Ripening is a very involved process in which the microbes present in the green cheese slowly change the chemical composition and so its texture and flavor. The change is overwhelmingly in the direction of dismantling complex organic molecules into simpler, smaller ones: lactose into lactic acid and carbon dioxide, fats into fatty acids, proteins into smaller chains of amino acids, individual amino acids, and even ammonia (NH_3) [1]. These and other exothermic processes are the reason for organization of continuous heat elimination from cheese.

Materials and methods

Technological parameters of food products (outward appearance, structure, fat and moisture content, et cetera) are closely connected with their thermal properties (intensity of heat transport, thermal conductivity, reflecting property and soon). This connection was demonstrated in [2] with adducing instances from dairy industry. Some of physical properties are typical technological characteristic at the same time – temperature, density, viscosity, temperature of melting or boiling [3]. Adaptation of newest thermophysical measuring devices permit to receive a new information concerning to technological processes, so permit to use sparingly of energy and raw materials.

Highly sensitive and fast-response compact heat meter – disc diameter of 20 mm and a thickness of 1,2 mm – was used during study of hard cheese ripening [4]. The temperature of air in camera was 10±0,25 °C in accordance with regulations.

Direct measurement of heat flux q, W/m^2 with heat meter, which was mounted at the top center surface of the piece of a green cheese with paraffin, for 22 th day of ripening, gave the curve taken on Fig.1. Result is unexpected: near 30 % of the heat which is released in the cheese and discharging with the cooling air is returned to the cheese.

Result and discussion

Return of heat to cheese is a ballast load for the chiller of ripening cheese chamber. Its elimination or minimization is a source of energy and resources saving.

To our knowledge, the fact that the return (inverse) of the heat flow in the refrigeration of food processing was not known either in domestic or in the world of science.

Perhaps this is due to the fact that this information was first obtained by direct measurement of the heat flux. Heat meter responds not only to turn on and off the refrigeration unit, but the fluctuation of the heat flow rate due to changes in the velocity of cooling air flowing around cheese, which are difficult to graphically display performance in computer graphics.

Ballast heat fluxes can occur not only in the refrigeration, but in the heat treatment of food products. For example, the results presented of the study of on Fig. 2 and 3 the process of stabilization of the surface layer of cooked sausages with oscillating infrared roasting. Heat meter diameter of 14 mm and a thickness of 1.5 mm was fixed at the inner side of the hollow cylinder, wherein the extrusion molded loaf recipe for milk sausage, and a second similar calorimeter under the surface layer 2.5 mm thick meat. After electric coagulation the piece of sausage loaf removed from the cylinder and placed in a heat chamber model for rotating cylindrical support. Energy supply to sausage was made with an infrared emitter (Fig. 2). The stabilization time of the surface layer (roasting) was 5 - 7 min, speed of the rotation - approximately 1 rev / min.

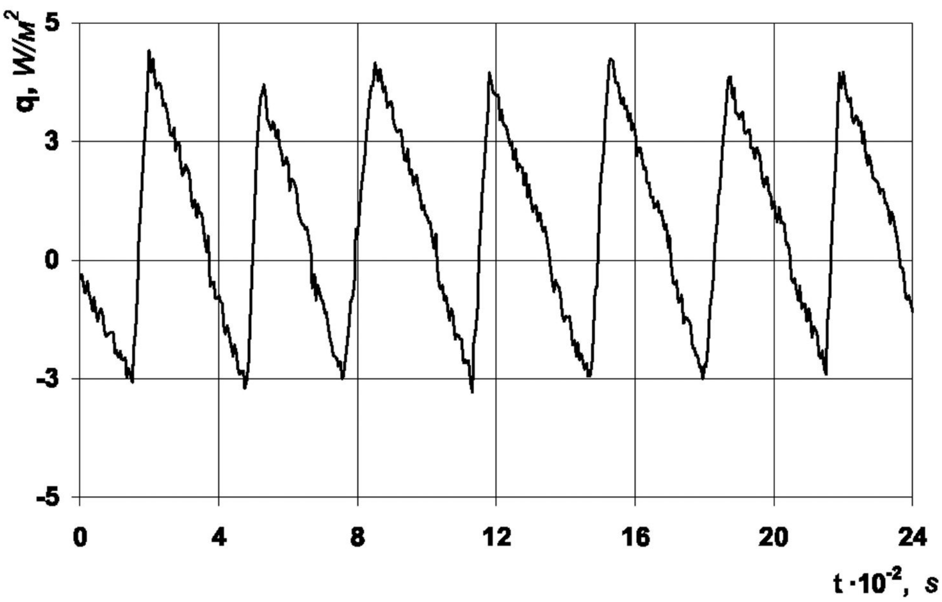

Fig. 1. The heat flux through the surface layer of the cheese during ripening.

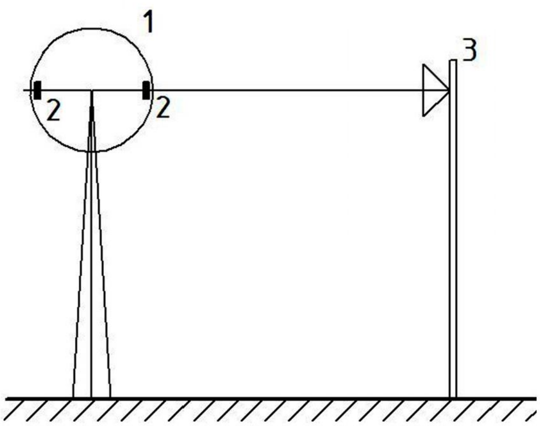

Fig. 2. Scheme of infrared stabilizing surface layer sausage
1 - long loaf sausage
2 - heat meters
3 - emitter.

Two heat meters were placed on opposite sides of the cylindrical sausage, so that when the signal of one of them is maximal (against the emitter), the second - close to the minimum or even negative (Fig. 3). Inversion heat flow occurs when the heat meter is on the opposite side (in shadow) between the transmitter and the ambient temperature is lower than the surface of the specimen. Thus, the cause of the reverse flow of heat is the same as in the cheese ripening - temperature difference "product surface - surrounding air" changes sign.

With the initial roasting regime parameters: temperature sausage after coagulation of 62 ° C, the maximum heat flux through the surface of the specimen 3 - 3.3 kW/m^2 (curve 1 on Fig. 3)- unnecessary for technology transit flow to the deeper layers (curve 2 Fig. 3) make up to two thirds of the resulting flow through the surface. Inversion of heat flow with heat meters is fixed not only on the surface of the sausage, but at a depth of 2.5 mm. The selection of the coagulation time and the voltage on the emitter managed to reduce ballast heat flux in the central layers to one-third (curve 1 in Fig. 4), and the inverse flow of these layers - to zero (curve 2 in Fig. 4).

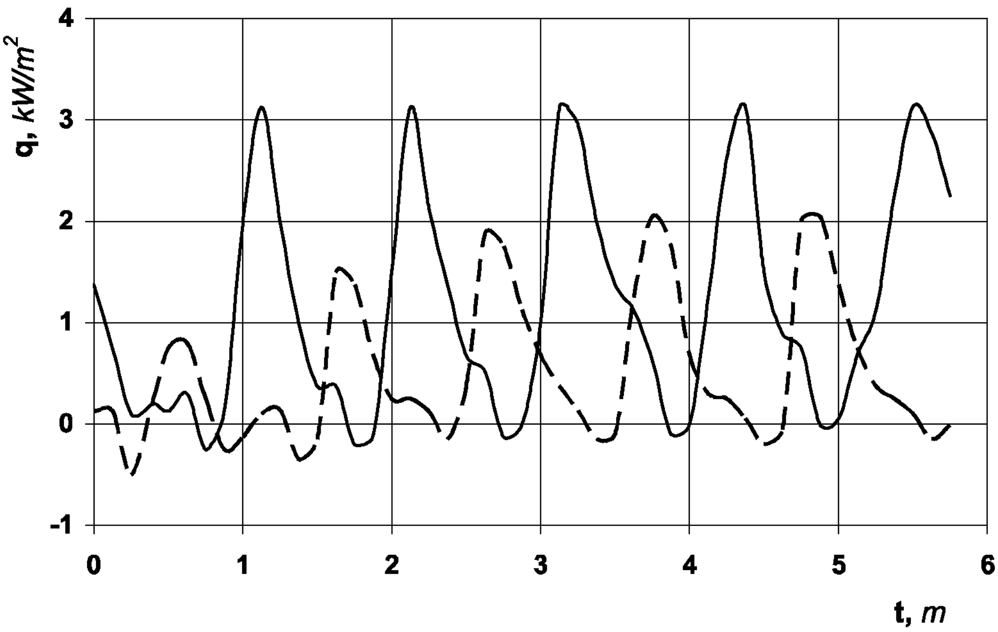

Fig. 3. The heat flux through the surface of the loafs (1) and a depth of 2.5 mm (2) before investigation.

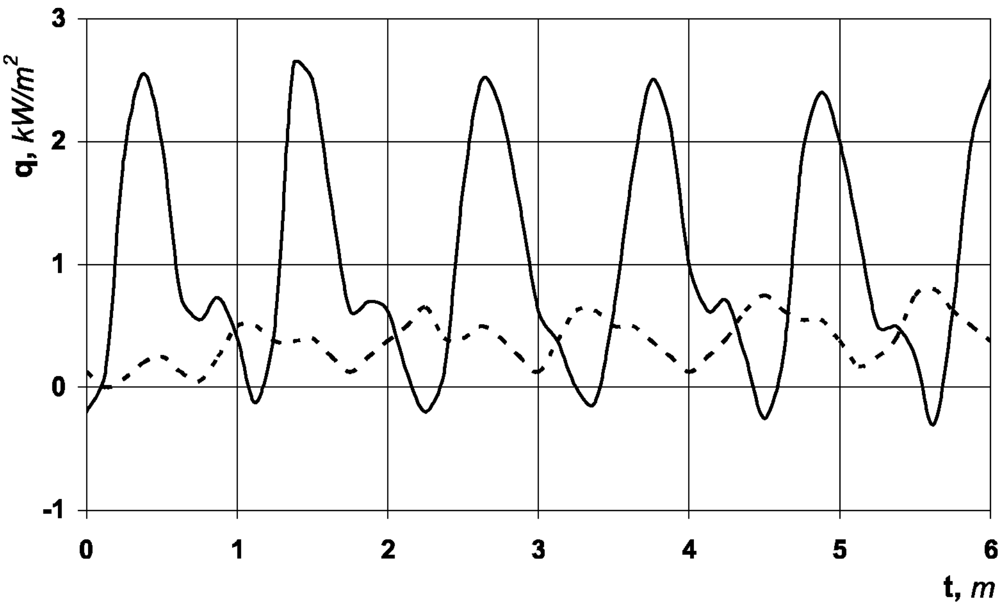

Fig. 4. The heat flux through the surface of the loafs (1) and a depth of 2.5 mm (2) after the selection of the parameters of rational roasting.

The maximum heat flux (and with it the total energy consumption) is reduced by 15-20 %. Thus, a direct measurement of the density of heat flow can develop rational modes of heat treatment of food products and identify features of thermal energy transfer that are not available in the measurement of temperature.

This is because the heat flux is determined not by the temperature at the point of product, but its gradient at this point in accordance with the first Fourier law

$$q = -\lambda grad\,(t) = -\lambda \frac{dt}{dn}, \tag{1}$$

where λ - thermal conductivity of the product, W/(m·K), n - the direction of heat transfer. The minus sign means that the vectors of the heat flux q, W/m^2 and the temperature gradient $grad(t)$, K/m, oriented in opposite directions. In other words, the temperature shows only potential of heat energy and density of the heat flow - direction and the intensity of its transfer.

Conclusion

If the heat treatment in the ballast heat flows relatively easy to fight, then the cooling process is necessary to make special arrangements. Thus, in the case considered cheese ripening heat removal was performed using a compressor refrigeration system and maintain the coolant temperature at 10 ± 0,25 °C thermostatic device produced. Reducing the temperature control range would reduce the amount of heat ballast, but would be reduced in proportion and amount of heat withdrawn per cycle "on-off". However, the cycle time would be reduced, which would lead to more rapid wear of chiller parts. The only side effect of reducing the useful range of temperature control is to reduce the thickness of the surface layer of cooled material, in which the alternating heat transfer.

The ideal solution to eliminate ballast flow of heat using compressor chillers is the availability of products in the treatment chamber buffer capacity - room, where the air is well mixed. If this is not possible, you need to install a thermostatic switch as far as possible from the chilled goods. Established fact that the possibility of ballast heat flows - one more argument in favor of a change to absorption chillers with heat recovery, the potential of which is large enough for any food enterprises, including dairy and cheese factory.

Regardless of which system is used of heat Abstraction, it is necessary to avoid inflow of fresh air into the cooling and freezing food, the heat leakage through the fence refrigerating compartment post including burning electrical lamps, because all this is a source of ballast heat flows.

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