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Patterns Of Food Thermal Processing In Electric Deep Fat Fryers

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Abstract-This paper deals with the studies of thermal processes occurring when heating a large volume of oil in continuous electric deep fat fryers with output of up to 150 kg/h, and during food roasting. The paper presents the results of experimental studies of the double deep fat fryer heating process, and their procedure. As a result of the conducted studies, we obtained the temperature-process time relationship *t* and the coefficient of heat transfer from the surface of the tubular electric heaters to oil. Obtaining experimental data on food heat treatment will ensure direct control of its quality and the quality of fry oil used for this process. Much attention was given to analyze the influence of fried food on thermal processing conditions. Special attention was paid to the design of a deep fat fryer and its main units, directly affecting the results of the experiments. Food deep frying improvement is a relevant task, since the existing methods of frying and the frying machines do not meet the growing demands of industrial technology. Main objective of this paper is to accumulate experimental data for further research on the development of reliable calculation methods and design principles of similar devices.

Keywords: deep fat, frying, temperature, thermocouple.

1. INTRODUCTION

Deep fat fryer is a specialized frying machine intended for cooking food products in large amount of oil [1]. Deep fat fryers are classified as intermittent or continuous heat-exchanging device. The main operating phases of the deep fat fryer ensuring its optimal operation are the period of deep fat heating up to a predetermined temperature, and food frying until readiness. Both of these processes are strictly non-stationary [2].

The existing specialized devices for deep fat frying, as a rule, do not meet modern requirements: high temperature of the heater surfaces leads to local overheating of deep fat and its rapid deterioration; devices feature high energy and materials consumption, and low coefficients of deep fat renewal, etc. The main reason for these shortcomings is the lack of reliable calculation methods and design principles of these devices, which leads to the need for comprehensive studies of heat- and mass transfer processes in order to obtain calculation formulas and develop new effective devices for deep frying on the basis thereof.

As is known, the deep fat fryers are widely used for frying various food such as flour products, fish products, potatoes, vegetables, etc. [3]. Various vegetable oil is a main process medium commonly used in the deep fat fryers. Therefore, we conducted our heating and frying experiments with the use of physically and chemically different palm oil and sunflower oil as a major process media, and compared their data on heating.

2. MATERIALS AND METHODS

Object of our experimental study was a continuous, double electric deep fat fryer for traditional frying of food products, with an output up to 150 kg/h. The capacity of each chamber - 400 l. The first chamber is designed for dough product swelling, and the second chamber is directly for frying. Thesetwochambersare separated by a partition.

Each chamber consists of 0.4 m^3 container *4*, with tubular heating elements *8* installed thereon, and a scraping conveyor with scrapers *5*. The container is covered with insulation *10* closed with housing *2* and the fryer cover *3*. The device is mounted on the frame *7* with a conveyor drive *1*, and fitted with testing *9* and control devices *6* (Figure 1). The test bench also included a thermometry system for determining the temperature of the fryer content, as well as the surface of the device housing and cover.

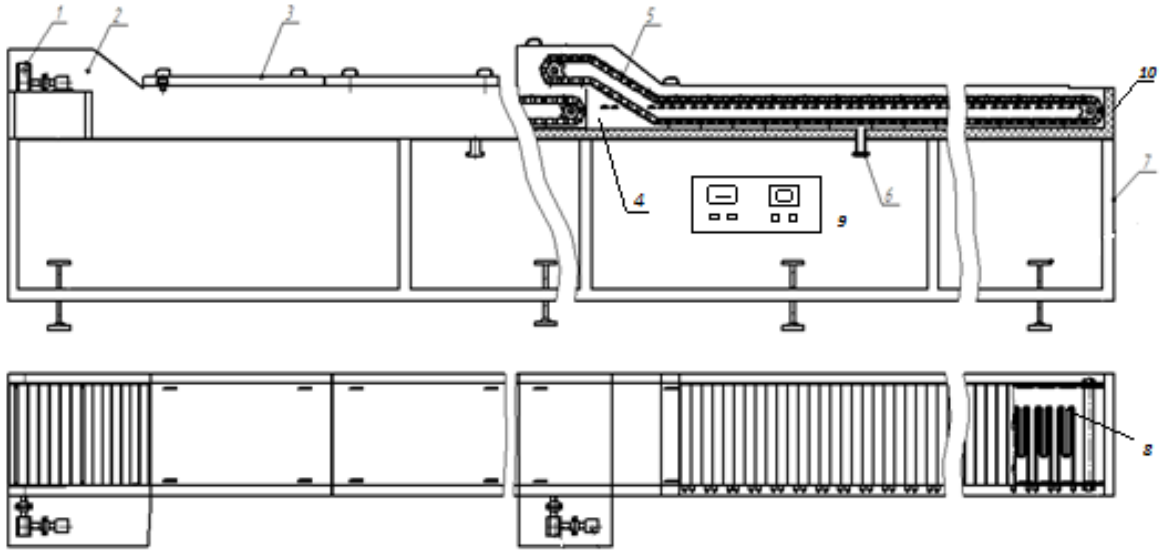


Fig. (1). – Scheme of the deep fat fryer main components

The process media temperature during the deep fat fryer heating was measured with chromel-copel thermocouples with 0.2 mm thermoelectrodes. The temperature of covers 3 was measured with a contact thermometer 12. At the same time, continuous automatic recording of temperature was carried out with the digital multimeter AM-1171, class 0.5.

Experimental studies of deep fat oil heating was carried out using K-type thermocouples, with their heads attached to the thermocouple grid (Figure 2). The temperature measurement was conducted on the oil surface in the immediate vicinity of the container walls and in the center of the oil volume.

In our experiment, we also recorded the oil temperature upon frying the flour food products. The experimental data were processed in accordance with the recommendations [4].

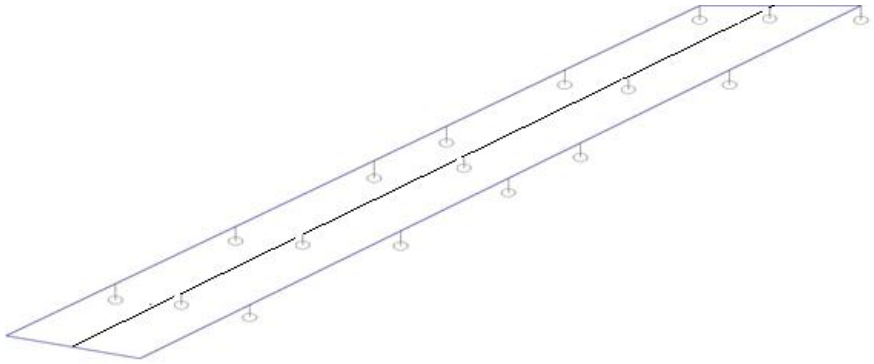


Fig. (2). – Thermocouplesarrangement

3. RESULTS AND DISCUSSION

As a result of the conducted experiments in the periods of deep fat oil heating (Figure 3) and frying of flour food products, we obtained the temperature-process time relationship t (×-oil central temperature, ♦ - oil surface temperature) and a thermophysical heat transfer parameter (⁕- the coefficient of heat transfer from the surface of the tubular electric heaters to oil).

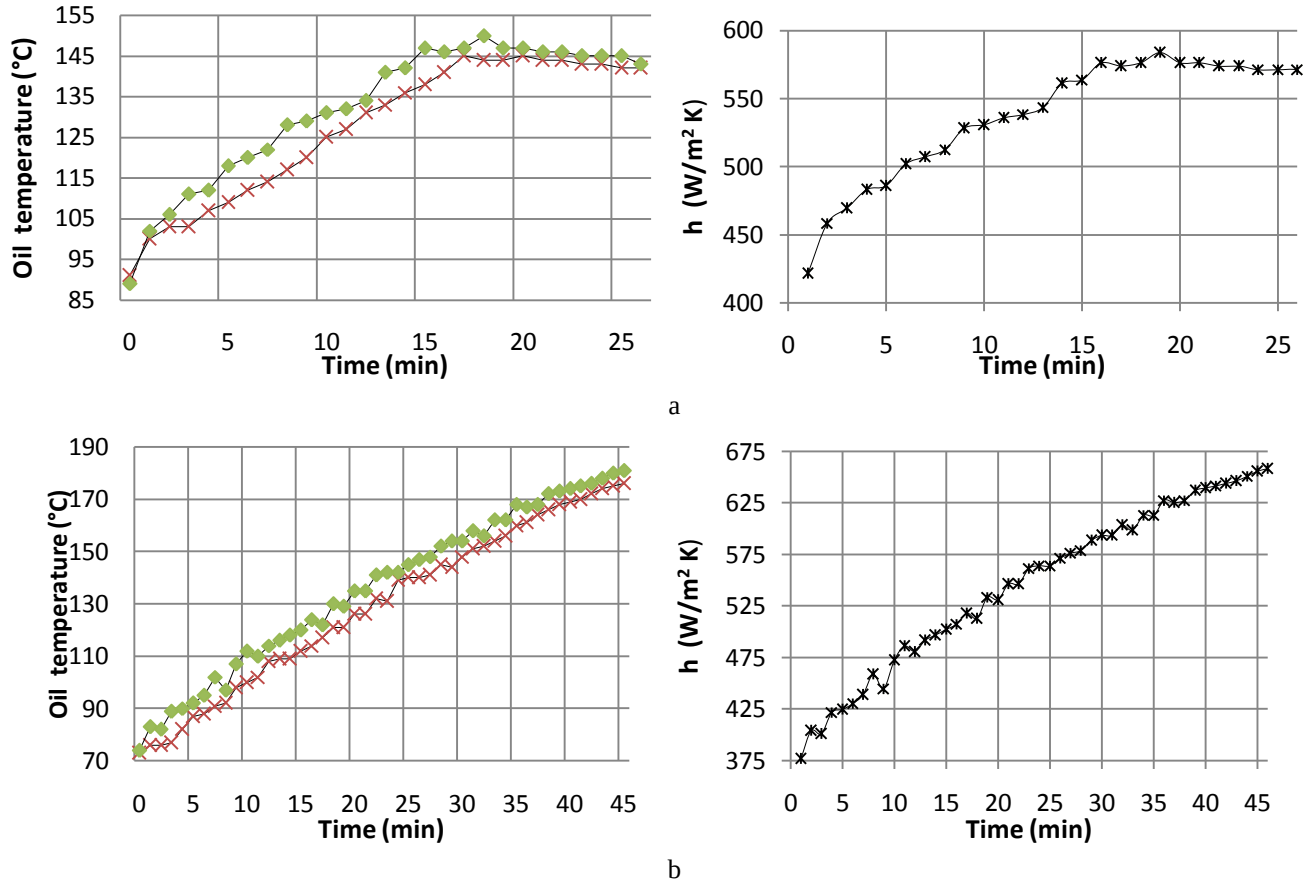
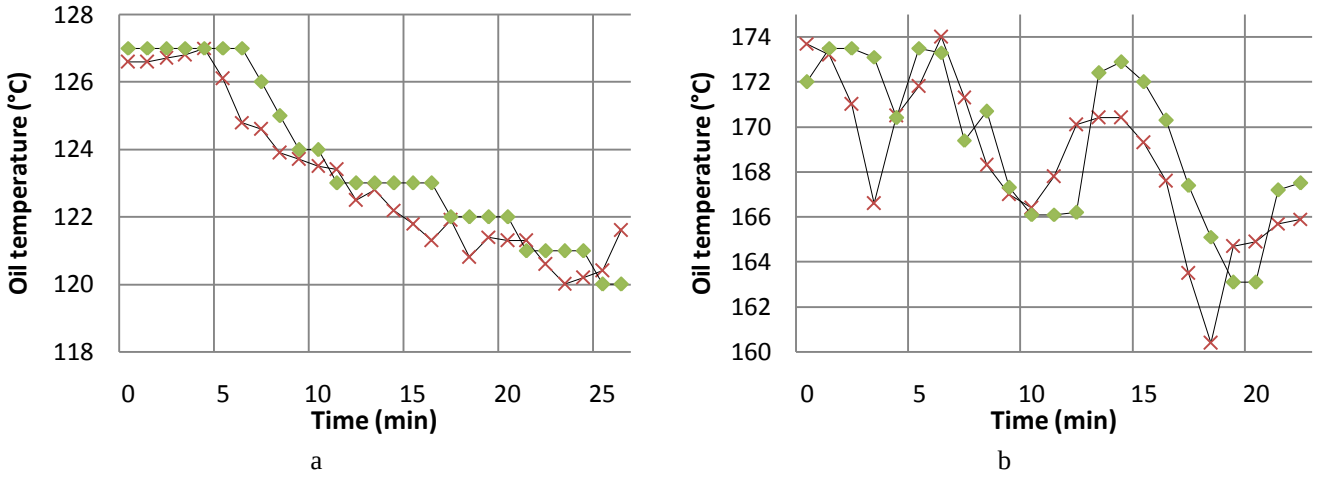


Fig. (3). – Temperature-process time relationship during oil heating (a – chamber 1 of the deep fat fryer, b – chamber 2 of the deep fat fryer)

Figure 4 shows the experimental data on the oil temperature change during food frying in the chamber 1 (a) and chamber 2 (b) of the electric deep fat fryer.



a b

Fig. (4). – Temperature-process time relationship during dough products deep fat frying

According to the experimental data shown in Fig. 3, 4, the products heating and frying periodscan be divided into shorter phases.

At the first stage, tubular electric heaters (TEH) heated the deep fat oil in both chambers of the deep fat fryer to a temperature necessary for production processes (the first chamber required 150°C, and the second chamber - 180°C). The first chamber reached the required oil temperature for t_{n1} = 18 minutes, while due to the difference in temperature regimes, the heating time of the

second chamber was t_{n2} = 44 min. By the end of this heating period, the heat transfer coefficient in both chambers of the deep fat fryer reached a maximum value.

Oil heating and the required temperature achieved in the deep fat fryer can be considered the beginning of the 2nd period of the frying process. Upon completion of the heating process, the TEHs are switched off. Oil temperature decreases slightly due to external heat loss [5].

Food feeding into the first chamber of the deep fat fryer is also the beginning of one of the final stages of thermal processing, followed by frying in the second chamber of the deep fat fryer. As can be seen from Figure 4, there is a discontinuous change in the oil temperature in both chambers, which leads to general reduction in its temperature.

All these experimental data suggest the complex physical and chemical processes that occur during food frying in the deep fat. The investigations are complicated by the presence of the scraping conveyor, which is in constant motion during the heating and frying processes.

It is known that the high oil temperature leads to changes in the temperature and the moisture content of the primary products from the initial values of these variables to values that characterize the state of readiness [6]. Processes such as oil absorption, changes in the structure and density of product tissues, formation of crisp, taste, and smell of roasted product occur during frying. Discontinuous change in temperature during the food frying can be explained by the type, shape, and size of a sample, oil temperature, heat transfer rate, and, to some extent, by the initial moisture content of the product [7].

4. SUMMARY

The obtained results allow us to come close to the creation of the thermotechnical calculation method for continuous electric deep fat fryers upon changes in the physico-chemical parameters of food products.

5. CONCLUSION

Thus, as a result of the conducted studies, we have determined real thermal conditions of food processing in the continuous dual deep fat fryer. We have found how the oil temperature changes during food products frying.

6. ACKNOWLEDGEMENT

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