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EQUIPMENT FOR HEAT TREATMENT WITH THE USE OF TECHNOLOGIES OF SUPER-HIGH-FREQUENCY AND ELECTRICAL CONTACT TECHNIQUE OF HEATING

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Abstract. The paper presents results of the development of equipment for heat treatment with the use of technologies of microwave and electrical contact methods of heating. The device for the combined frying of culinary products and the device for microwave heating with vacuuming are examined. Effectiveness of the processes and apparatuses is determined.

Keywords: equipment, thermal treatment, electro-physical methods, microwave heating, vacuuming, electric contact heating

Thermal treatment in food industry enterprises is characterized by long-term production processes, energy intensity, high expenses of material resources, low coefficient of capacity, in some cases the product doesn't correspond quality criteria. Improvement of the manufacture is possible during the development of new, and improvement of the existing equipment, development of rational parameters of technological processes.

Such work cannot be fulfilled through the application of electric-physical methods of treatment alongside with the traditional heat processes. This is predetermined by the considerable preferences of electric-physical methods, which are concluded in the fleetness of processes, energy saving, evenness of thermic area according to the dimensions of semi-finished product etc.

Nevertheless, despite certain preferences, application of electric-physical methods in some cases doesn't allow getting the product with the required properties, e.g. it is impossible to get fried crust on top of the products (electrocontact heating); thermal treatment by microwave heating takes place at the temperature 95…100 °C that results in big losses of biologically active substances.

It is possible to exclude such negative factors due to combining various methods of thermal influence.

Taking into account all the above-mentioned, the purpose of the paper is to develop equipment for thermal treatment with the use of microwave and electrocontact heating technologies.

During the patent search and literature analysis the preferences and drawbacks of the traditional technological processes, methods and constructions of thermal apparatuses are determined.

Such thermal processes as roasting and baking are provided in cabinet and bakery ovens. Chopped culinary products are fried in electric frying-pans [1, 2, 3].

Long process time and losses of mass, high specific losses of heat, the necessity of using additional thermal apparatuses are general drawbacks of such devices. That promotes additional energy losses and high labour intensity.

Electric contact heating is a famous method of thermal treatment [4, 5]. A device, in a permeable chamber of which the semi-finished product is placed, works this way [6]. Current electricity is passed through it that leads to the heating of the chamber.

Absence of crust on the surface of a product is a disadvantage. Ready products possess the properties of boiled ones but getting fried production is possible only under conditions of additional thermal processes.

As for the processes of thermal treatment of fine substances in the form of plant raw materials, well-known constructions of microwave ovens used for this purpose, consist of the following main units – carcass, process chamber, mitron with wave-guiding system, fan for mitron cooling and air-cooling of process chamber, thermal switch for the protection of the oven from overheat, and control module [7].

The general drawbacks include high temperature of steam in the product, which leads to structural changes as well as to the formation of super high pressure breaking wholeness of food systems, lowers quality of a ready product. Besides in such apparatuses it is impossible to process crushed food systems, which require mixing during the microwave treatment and dehydration from the operating zone of the apparatus.

Obtained information about technological processes and apparatuses allowed developing new devices for the combined thermal treatment.

The device for combined frying of chopped culinary products [8] consists of two pivotally connected slabs. In the lower slab there are hollows where thermal elements are located. The upper slab and the lower one in which thermal elements are located, form the environment for products during the compression. Retention pins, where upper working surfaces – namely electrodes and electric heating elements – are fixated into the upper slab by means of springs. Along the perimeter of the slabs there are special grooves for heat-resistant gaskets from rubber.

At the front of the device a command console and a unit with measuring instruments and current switch in an electrical circle are mounted.

During the turning on of a "Net" switch on a command console, electric current is supplied. To start warming up of an electrode surfaces, position of temperature control is changed to the one different from zero. When the required temperature of electrode surfaces is achieved, temperature detector activates, and further on the temperature is regulated automatically. On the controller of electrocontact heating parameters are set with the help of a switch key. After this the formed chopped semi-finished products are placed on the lower electrodes. Pushing the button "Start", an electrical contact heating is switched on. Duration of thermal treatment is fixed by means of a timer. When the time of treatment is over, heating is discontinued.

The main advantages of the described method and a frying device are reduction of the duration of technological process, reduction of energy losses due to the combination of superficial and infra-red heating with an electrical contact, provision of uniform heating for all layers of the product according to its volume, and, correspondingly, high quality of ready products.

A number of experimental investigations were held for the determination of rational parameters.

During the investigation of electrocontact heating, sufficient reduction of the temperature field unevenness was determined, which constituted not more than 7…9 ^{0}C according the sample's volume (figure 1). At the same time a little higher temperature is observed in near-electrode layers as the result of electrodes' heating under the influence of electric current.

It was also noticed that during the application of alternating current of electrocontact heating duration from 20 to 90 ^{0}C in comparison with the direct current reduces approximately to 3 - 4 times (figure 2).

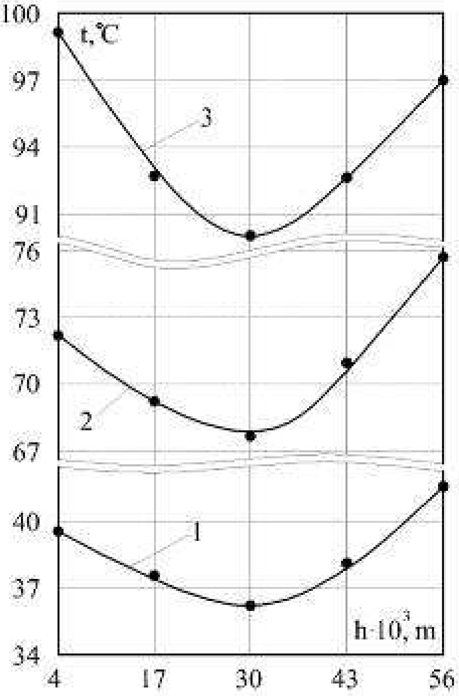

Figure 1. Division of the temperature field during electrical contact heating of samples of natural cutlet farce by 40 V alternating current from the very beginning of the process: 1. 90 s; 2. 180 s; 3. 270 s

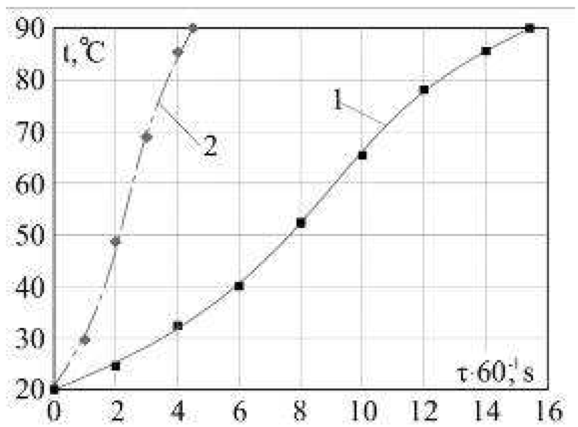

Figure 2. Kinetics of the temperature during electrical contact heating of natural cutlet farce:
1. direct current with 40 V voltage; 2. alternating current with 50 Hz frequency of a sine and orthogonal waveform (40 V net voltage)

Increase of the electric current frequency from 0.1 to 300 Hz allows raising average electric conductivity of the sample about 29 ... 30 % and reduce of electrocontact heating duration approximately by 53 ... 54 %. At the same time growth of an average electrical conductivity and reduction of the duration is observed only up to the frequency 40…50 Hz, after which these indexes remain stable.

Besides during of electrocontact heating by the alternating current product output is 13 % higher than during of electrocontact heating by direct current. With the increase of frequency from 5 to 20 Hz a tendency to the growth of output from 85 to 87 %, and at 30 Hz – to 89% is observed. At the same time mass losses do not change in the frequency intervals 30…50 Hz (figure 3).

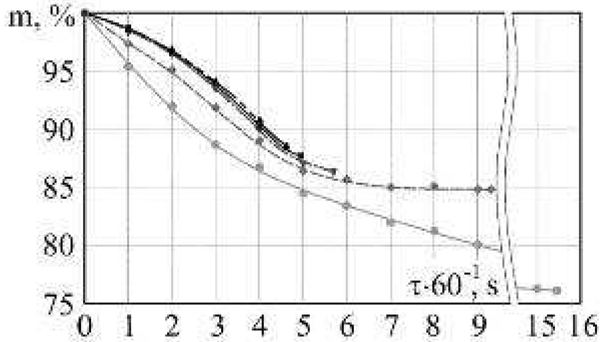

Figure 3. Dynamics of mass of natural cutlet farce during EKH by a current with 40 V voltage:
● - direct current; alternating current: ♦ - 5 Hz;
▼ - 10 Hz; ■ - 20 Hz; ▲ - 30…50 Hz

The device for the concentration of food systems with the use of microwave-heating and vacuuming [9] provides the possibility of treatment with simultaneous interfusion with rational regimes of thermal influence.

The device consists of a microwave oven, in which the reservoir is placed. An electric drive with a mixer is fixed in the upper part. On a lateral face of a microwave oven there is an outlet for the derivation of condensate with a vacuum manometer and a condensate trap. For the regulation of condensate trap a faucet is used. Vacuum is supported with the help of vacuum pump. A tachometer is located in an upper part of electric drive.

Work of the device is concluded in the following: finely graded raw material is placed into the process chamber of a microwave oven after that it is fixated. A mixer's working element is put on the axis, and the door of a microwave oven is closed. A vacuum pump is switched off and the pressure is controlled with the help of a vacuum manometer. After that a microwave oven and an electric drive are switched on. Speed of a mixer is controlled with the help of a tachometer. The temperature in a working chamber of a microwave oven depends on the exhaustion in a working area of a chamber and is regulated by means of a faucet. The time of treatment depends on the type of raw material.

If required the device can also work without a mixer.

The following can be considered the main advantages of the developed concentration (drier) installation of a microwave oven and vacuuming: reduction of the process duration due to the application of interfusion in a working chamber of a microwave installation; losses of biologically active substances due to vacuuming decrease.

The investigation of thermal processing of fine-dispersed products on the basis of plant raw materials was held on the experimental device. High organoleptic indexes of ready production and semi-finished products quality in comparison with the existing traditional technologies were received in the result.

For the determination of main factors influencing the process of concentrating spicy-aromatic raw materials (parsley, parsnip, dill and celery) and choice of the equipment (microwave heating and vacuuming) the concentration of boiling water was made and dependence of dielectric penetrability and factors of dielectric losses from temperature was determined for various density, humidity, presented in figures 4 and 5 on a frequency of 2450 mHz in the interval of temperature 20…80 ºC, humidity 5…90 %.

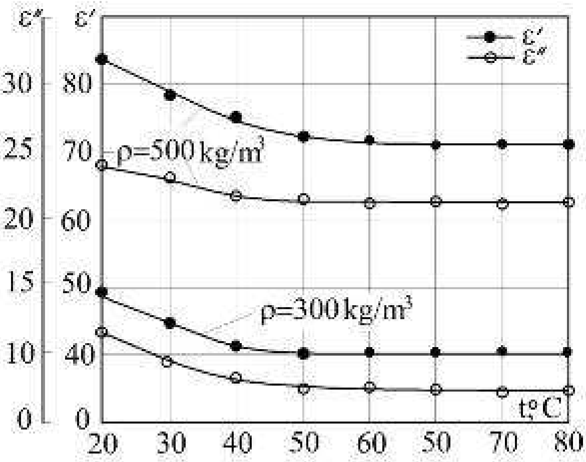

Figure 4. Dependence of dielectric penetration and factor of dielectric losses on temperature for various densities (2450 mHz)

Analysis of figure 4 means that $\varepsilon^{/}$ changes from 24 to 14, $\varepsilon^{//}$ = 16…15 corresponding with the density 500…300 kg/m^3, $\varepsilon^{//}$ = 8…2.8, $\varepsilon^{//}$ = 5.5…5.2.

Analysis of figure 5 with W = 85%, $\varepsilon^{/}$ = 0.9, $\varepsilon^{//}$ = 0.25, but with W = 8%, $\varepsilon^{/}$ = 0.9, $\varepsilon^{//}$ = 0.3.

Chemical composition of ready production under the temperatures 40…50 ^{0}C and pressure 40…59 kPa of pastes, purees and powders, allowed saving vitamin C in the amount 20 % that improves quality of the product.

Volatile oil in semi-finished products and in ready production doesn't change as compared to raw materials. It allows using the received products for the needs of food and catering industry.

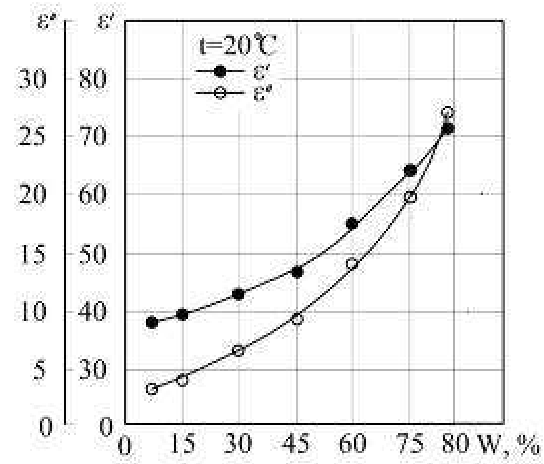

Figure 5. Dependence of dielectric constants ($\varepsilon^{/}$, $\varepsilon^{//}$) of boiling water from humidity on frequency (2450 mHz)

So, during the investigation the preference of this method of treatment was experimentally determined. It is concluded in the evenness of temperature field according to the volume of the sample (difference in the temperature cannot exceed 7…9 ^{0}C). A little higher temperature is observed in near-electrode layers.

The expediency of applying alternating electrical current is determined. Expedient frequency equals 40…50 Hz.

Research of the concentration processes allowed stating that main factors influencing the process are dielectric ones.

Characteristics of the concentration processes, speed of moisture removal and temperature will depend on raw material in the conditions of maximum maintenance of biologically active substances.

The received data are basic for the combination of mixtures on the basis of spicy-aromatic vegetables, and can be used for the development of normative-technical documentation on new models of apparatuses.

Thus, combined processes of electrical control heating with the surface heating as well as microwave heating with vacuuming give a number of energetic preferences, quality parameters and rational regimes of treatment, which is an important argument for their introduction into manufacture.

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