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FEATURES OF MICROWAVE HEATING EQUIPMENT IN THE HOTEL AND RESTAURANT BUSINESS AND FOOD INDUSTRY

Antonenko A. V. *– Ph.D. in Technical Sciences, Associate Professor,*
Associate Professor at the Department of Computer Engineering
State University of Telecommunications
ORCID ID: 0000-0001-9397-1209

Brovenko T. V. *– Ph.D. in Technical Sciences, Associate Professor,*
Associate Professor at the Depatment of Hotel and Restaurant
and Tourist Business
Kyiv National University of Culture and Arts
ORCID ID: 0000-0003-1552-2103

Zemlina Ju. V. *– Ph.D. in Pedagogical Sciences, Associate Professor,*
Associate Professor at the Depatment of Hotel and Restaurant
and Tourist Business
Kyiv National University of Culture and Arts
ORCID ID: 0000-0003-0194-9472

Kryvoruchko M. Yu. *– Ph.D. in Technical Sciences, Associate Professor,*
Associate Professor at the Department of Design and Engineering
State University of Trade and Economics
ORCID ID: 0000-0002-7378-1050

Tolok G. A. *– Ph.D. in Technical Sciences, Associate Professor,*
Head of the Department of Standardization and Certification
of Agricultural Products
National University of Life and Environmental Sciences of Ukraine
ORCID ID: 0000-0002-2971-1645

Vasilenko O. V. *– Ph.D. in Pedagogical Sciences, Associate Professor,*
Associate Professor at the Depatment of Hotel and Restaurant
and Tourist Business
Kyiv National University of Culture and Arts
ORCID ID: 0000-0003-4097-7476

The article describes the features of the interaction of microwave energy with food raw materials and food products and conducts an analytical review of the application of microwave processing for various technological processes in the food industry and hotel and restaurant business. The paper examines the peculiarities of the interaction of microwave energy with food raw materials and food products and gives an overview of the application of microwave processing for various technological processes in the food industry and the hotel and restaurant business. Despite the number of scientific works devoted to the topic of technological equipment, in particular, microwave heating, in Ukraine this is an insufficiently illuminated topic that requires research, taking into account the current conditions in the national economy. To create more rational technological processes, a combination of microwave heating with other energy carriers is used: steam, hot air, infrared heating, heated fat, vacuum, ultrasound. Heat treatment of food products in the cooking mode is divided into two stages: heating to a set temperature and maintaining this temperature until complete culinary readiness. The stepwise microwave heating method is also used, which ensures a high heating rate and avoids uneven heating of individual areas of the processed products. In this way, the possibility of temperature redistribution is ensured through the thermal conductivity of the material during its thermostating. One of the features of microwave processing is the possibility of rapid and relatively uniform heating of the product throughout the entire volume, which by its nature depends not so much on the thermophysical characteristics of the heated object, but on the presence of moisture in it and the nature of its distribution by volume. The ability of dielectric heating is effectively used in the food industry when defrosting products. Defrosting in the microwave field allows you to speed up the process tenfold and to a large extent preserve the quality of food products. Good results are given by combined methods of defrosting microwave heating with ultrasound, as well as with the method of blowing the product with cold air. The use of microwave heating with other physical methods and energy carriers makes it possible to intensify technological processes, reduce the cost of finished products, as well as increase the nutritional and biological value of raw materials, semi-finished products and finished products

Key words: *technological equipment, microwave energy, thermal processes, microwave heating, induction field.*

Антоненко А. В., Бровенко Т. В., Земліна Ю. В., Криворучко М. Ю., Толок Г. А., Василенко О. В. Особливості мікрохвильового нагрівального обладнання в готельно-ресторанному бізнесі та харчовій промисловості

У статті наведено особливостей взаємодії НВЧ-енергії з харчовою сировиною та продуктами харчування та проведення аналітичного огляду застосування НВЧ-обробки для різних технологічних процесів у харчовій промисловості та готельно-ресторанному бізнесі. У роботі розглянуто особливості взаємодії НВЧ-енергії з харчовою сировиною та продуктами харчування та наведено огляд застосування НВЧ-обробки для різних технологічних процесів у харчовій промисловості та готельно-ресторанному бізнесі. Незважаючи на кількість наукових доробок присвячених темі технологічного устаткування, зокрема НВЧ-нагріву, в Україні це недостатньо освітлена тема яка вимагає дослідження враховуючи умови сьогодення в національній економіці. Для створення раціональніших технологічних процесів використовують комбінацію НВЧ нагрівання з іншими енергоносіями: пар, гаряче повітря, ІЧ-нагрів, розігрітий жир, вакуум, ультразвук. Теплова обробка харчових продуктів в режимі приготування поділяється на два етапи: розігрів до температури, що встановилася, і підтримання цієї температури до настання повної кулінарної готовності. Також застосовується метод ступінчастого НВЧ-нагріву, який забезпечує високу швидкість нагріву та дозволяє уникнути нерівномірності нагріву окремих ділянок оброблюваних виробів. Таким чином забезпечується можливість перерозподілу температур шляхом теплопровідності матеріалу при його термостатуванні. Однією з особливостей НВЧ-обробки є можливість швидкого і відносно рівномірного нагріву продукту по всьому об'єму, який за своєю природою залежить не стільки від теплофізичних характеристик об'єкта, що нагрівається, скільки від наявності в ньому вологи і характеру її розподілу за обсягом. Здатність діелектричного нагріву ефективно використовується у харчовій промисловості при розморожуванні продуктів. Розморожування у НВЧ-полі дозволяє в десятки разів прискорити процес та значною мірою зберегти якість харчових продуктів. Хороші результати дають комбіновані методи розморожування НВЧ-нагріву з ультразвуком, а також з методом обдування продукту холодним повітрям. Застосування НВЧ-нагріву з іншими фізичними методами та енергоносіями дозволяють інтенсифікувати технологічні процеси, знизити собівартість готової продукції, а також підвищити харчову та біологічну цінність сировини, напівфабрикатів та готових виробів.

Ключові слова: *технологічне устаткування, НВЧ-енергія, теплові процеси, НВЧ-нагрів, індукційне поле.*

Introduction. Currently, in the food industry and the hotel and restaurant industry, special attention is paid to physical methods of influencing raw materials, semi-finished products and finished products, which are capable of intensifying heat exchange processes, ensuring microbiological safety, as well as improving and increasing the nutritional value of food raw materials. A physical method capable of achieving these goals is heating in an electromagnetic field. The paper examines the peculiarities of the interaction of microwave energy with food raw materials and food products and gives an overview of the application of microwave processing for various technological processes in the food industry and the hotel and restaurant business. Despite the number of scientific works devoted to the topic of technological equipment, in particular, microwave heating, in Ukraine this is an insufficiently illuminated topic that requires research, taking into account the current conditions in the national economy.

Formulation of the problem. Modeling heat treatment of food products is a process of creating a product as a single integrated system consisting of elements that do not individually provide the specified properties. Conceptual approaches to the modeling of heat treatment and regimes based on them consist in optimizing the choice and ratio of methods by which it is possible to obtain a finished product that, in terms of quantitative content and qualitative composition, corresponds to nutritional value indicators and medical-biological requirements to the greatest extent. The use of various heating methods allows you to qualitatively process food raw materials and products in the shortest possible time.

The aim of the study. The purpose of the article is to study the peculiarities of the interaction of microwave energy with food raw materials and food products and to carry out an analytical review of the application of microwave processing for various technological processes in the food industry and hotel and restaurant business.

The object of the research is the peculiarities of the interaction of microwave energy with food raw materials and dishes.

The subject of research is technological equipment, microwave energy, thermal processes, quality and safety.

Analysis of recent research and publications. Scientific substantiation and development of thermal processing technologies for various types of food products based on thermal energy is an urgent task, the solution of which will allow expanding the range of dishes with increased nutritional and biological value and obtaining products with specified functional properties.

A significant contribution to solving the fundamental issues of creating technologies and equipment for food products with complex raw materials as a means of preventing and eliminating micronutrient deficiencies was provided by the research of the following domestic and foreign scientists: O.O. Grinchenko, A.B. Horalchuk, A.M. Dorokhovych, I.Yu. Zhigalenko, A.V. Ziolkovskaya, P.O. Karpenka, M.B. Kolesnykova, V.N. Korzuna, M.V. Kravchenko, H.M. Lysyuk, L.P. Malyuk, L.M. Mostovoi, N.Ya. Orlova, M.I. Peresichny, P.P. Pivovarova, N.V. Prytulska, G.B. Rudavska, M.R. Ennis, J.C.F. Murray, G.O. Phillips, W.C. Weling, P.A. Williams and others [1–13].

Presentation of the main research material. The heating of bodies, in particular food products, in an electromagnetic field differs from their heating due to heat conduction or convection in that the elements of the medium that separates the generators of electromagnetic oscillations and the objects of heating, as a rule, do not participate in the transfer of heat. Therefore, in such systems (generator – medium – heating object) the heat flow is not continuous and the energy is transferred in the form of electromagnetic waves. Heat arises in the objects of heating themselves due to its interaction with the electromagnetic field. Electromagnetic waves of the appropriate frequency ν and length can be used in the production of food products to implement three main methods of heating bodies; infrared (IR), dielectric (DE) and induction (ID). It is worth noting that with IR and DE heating, food products are directly heated, while with IR heating, only some ferromagnetic part of the device is heated [1; 2; 4].

Dielectric heating is a method of heating dielectric materials with a time-varying electric field. Ultra high frequency (UHF) heating is the use of ultra high frequency electromagnetic field energy with a frequency range of 3·108 – 5–3·1010 Hz to heat various environments and bodies. According to the international agreement on the division of frequencies, frequencies of 895–915 MHz and 2350–2450 MHz are used for microwave installations [5–7].

From an electrophysical point of view, food products should be classified as semiconductors. Food products are, as a rule, complex heterogeneous systems containing water in the amount of 50–95 %. From the point of view of the interaction of food products with the electromagnetic field, their components such as proteins, fats, carbohydrates, and water should be classified as non-ideal dielectrics, and aqueous solutions of salts (electrolytes) as conductors. When an external electric field is applied, displacement currents that reflect the dielectric properties and conduction currents that reflect the movement of free charges arise in the product. The latter are always present in wet food products, as alkalis, acids and salts dissociate in water, resulting in the formation of ions and active conductivity of the material. The effect of heating food products in an ultrahigh-frequency (UHF) field is mainly (but not entirely) related to their dielectric properties, which are determined by the behavior of dipoles in such a field. Dipoles (dipole molecules and atoms) can be present in a food product, for example, water molecules, or arise in it under the influence of an external electric field.

The orientation of already existing dipoles, and even the emergence of new dipoles and its orientation under the influence of an external electric field constitute the essence of polarization. It occupies a central place in the mechanism of heat generation in bodies located in the microwave field. The energy of the external field, spent on the polarization of the dielectric, is transformed into heat in it, and the heat occurs in the entire volume of the material, and not only on its surface. Therefore, DE-heating is often called volume heating. Dielectric properties of food products and various materials depend mainly on their nature, humidity, temperature and frequency of field oscillations. The complex nature of the interaction between the amount of heat released and the depth of penetration of the microwave field leads to the need to select a product of such thickness that overheating of its outer (with large values of the absorption coefficient) and internal (with small values of the absorption coefficient) layers is not observed [8]. Microwave heating has a number of advantages over traditional methods of heat treatment:

– high rate of heating and its uniformity due to "volumetric" heat supply;
– preservation of vitamins and other essential nutrients of the food product;
– the possibility of a moderate mode of heat treatment, heat supply in pulses, i.e. step heating;
– creation of a given temperature unevenness during heat treatment of food products by selecting the shape of the microwave generator's working bodies or by using curtains (screens) that regulate the transmission of microwaves to the product;
– high efficiency of the process (the absence of contact with the heat carrier and the generation of heat in the product itself minimize heat loss to heat the equipment and to the environment;

– the consumption of electricity by microwave generators is much less than by electrolytes and other heating devices);

– improvement of working conditions by reducing the release of gaseous substances, steam and heat into the environment [9].

However, DE-heating has a drawback, which is the absence of a specific fried crust on the surface of the products. Therefore, DE heating is recommended to be used in combination with IR heating and traditional methods of heat treatment [10].

Currently, microwave processing is used in the hotel and restaurant business and the food industry in the following processes: heating and preparation of dishes, drying, defrosting, cooking, baking, disinfection, extraction, as well as as a stimulating factor aimed at intensifying technological processes and increasing food values of raw materials, semi-finished products and finished culinary products. To create more rational technological processes, a combination of microwave heating with other energy carriers is used: steam, hot air, infrared heating, heated fat, vacuum, ultrasound. The most common way of using microwave energy is heating and cooking dishes and culinary products. Heat treatment of food products in the cooking mode is divided into two stages: heating to a set temperature and maintaining this temperature until complete culinary readiness. The stepwise microwave heating method is also used, which ensures a high heating rate and avoids uneven heating of individual areas of the processed products. In this way, the possibility of temperature redistribution is ensured through the thermal conductivity of the material during its thermostating. One of the features of microwave processing is the possibility of rapid and relatively uniform (gradient-free) heating of the product throughout the entire volume, which by its nature depends not so much on the thermophysical characteristics of the heated object as on the presence of moisture in it and the nature of its distribution by volume This ability of dielectric heating is effectively used in the food industry when defrosting products. Defrosting in the microwave field allows you to speed up the process tenfold and to a large extent preserve the quality of food products. Moisture loss in products during defrosting in the microwave field is negligible. Good results are given by combined methods of defrosting microwave heating with ultrasound, as well as with the method of blowing the product with cold air [4; 6; 7].

In scientific papers, the technology of defrosting hydrobionts in the microwave microwave field was developed, which made it possible to reduce the time of technological processes by 4–15 times, as well as to increase the nutritional and biological value of finished products. Fibers and microstructure of muscle tissue at the cellular level are preserved better and more integrally, pH values are stable. Protein denaturation changes are insignificant, characterized by an increased level of solubility of sarcoplasmic (by 16–20 %) and myofibrillar (by 19–27 %) fractions 2 by the content of essential amino acids (methionine, cysteine, leucine, isoleucine by 9–31 %), the degree of hydrolysis and oxidation of lipids is 1.5–3 times lower, which ensures an increased total content of polyunsaturated biologically active fatty acids from 3 to 8–16 % [5].

Similar results were obtained when defrosting meat in blocks with microwave energy. In [8], a method of defrosting apple fruits under the influence of microwave energy is proposed. At the same time, the duration of the thawing process is reduced by more than 20 times, but the content of dry substances increases, and the organoleptic indicators of thawed fruits improve. Due to the peculiarities of the interaction of microwave energy with food raw materials and products, drying in the microwave field ensures uniform heating of the product, and the efficiency of the process practically does not depend on the thermal conductivity of the drying material and is determined only by the moisture content in the product. Areas with a high moisture content heat up most intensively, but as the humidity decreases, the heating rate decreases. This makes it possible to exclude overheating of the product and deterioration of organoleptic indicators. At the same time, losses of nutrients and primarily vitamins are significantly reduced. As a result of volumetric heating of products during microwave drying, all free moisture inside turns into steam. At the same time, excess pressure is created, as a result of which the product increases in volume and acquires a porous structure. This is of great importance in the technology of fast food products, such as beverages, cereals, soups based on vegetables, fruits or grains. The most promising combined drying: convective drying and microwave drying [9]. In devices with a microwave source, the intensity of the process of drying compound feed and grain increases by 5–10 times [10].

In the works of the authors, it was proposed to use the energy of the ultrahigh-frequency (HF) field for vacuum-sublimation dehydration of food products. The nature of microwave heating allows for a sharp intensification of the processes of heat and mass exchange, since the heating of the product occurs throughout the volume and the temperature and humidity gradients coincide in the direction [6].

In the works of scientists, the advantage of using microwave energy for drying coriander seeds compared to convective drying is substantiated [7]. When cooking and blanching using the energy of the microwave field, the duration of processing and the loss of food substances are reduced. Scientists have developed a high-frequency device for cooking chopped raw meat. This installation made it possible to increase productivity and reduce economic costs.

The use of microwave field energy for the extraction of oils from vegetable raw materials allows you to speed up the process, achieve almost complete extraction of oils, and preserve the nutritional and biological value of the finished product [10]. Thus, in scientific papers, a scheme for microwave extraction of biologically valuable components from plant raw materials (eucalyptus leaves) is proposed. It has been established that under the influence of microwave energy, essential oils (up to 99.5 %) and soluble salts are extracted as completely as possible. At the same time, the speed of extraction is higher than with steam extraction. Intensification of the extraction process occurs due to the occurrence of excessive pressure inside the tissues due to steam formation. The resulting water vapor "pushes" substances from the cells to the leaf surface [10].

Microwave heating can also be successfully used to process raw materials with active enzymes (for example, malt products, grain, plant seeds), thereby regulating and achieving the desired enzyme activity indicators [11; 12].

Depending on the processing modes, it is possible to increase the activity or cause the inactivation of enzymes. In agriculture, microwave treatment of seeds before sowing helps to increase their germination and viability. The stimulating effect of microwave energy is explained by the stimulation of active centers of enzymes involved in the processes of seed germination, as well as an increase in the permeability of cell membranes due to the formation of free radicals, which contributes to a better supply of cells with oxygen and water. Microwave processing has become widespread in the bakery and confectionery industry. Microwave processing is widely used to disinfect and improve the nutritional value of grain. Under the action of a microwave field with a heating rate of 0.4–0.6 °C/s and an exposure of 60 s, a disinfecting effect is observed during storage, and in some cases, an improvement in the food qualities of grain and its processing products. Microwave processing of food grain wheat leads to an increase in its baking qualities due to the improvement of the physical properties of gluten, as well as a decrease in the content of starch in wheat grains, an increase in hydrolysis, which positively affects the baking qualities of products [13]. A similar decontamination effect can be observed in the processing of dried fruits, decontamination of dried fruits from sporulation by species of the genera Mucor, Pynicillium, Phomopsis and general microbial contamination occurs [14].

When the yeast semi-finished product is treated with an ultra-high frequency electromagnetic field (microwave field), the fermentation process is intensified. A strong electric field, acting during kneading, intensifies dough fermentation processes and increases the rate of CO_2 release and dough rising with increasing temperature from room to 30 °C [11].

Carrying out the dough proofing process in the microwave field at a power of 250–500 W for 10–40 seconds during the production of flour products reduces the duration of the process and allows you to significantly improve the quality of the finished product [12]. When baking in an ultra-high-frequency electromagnetic field, the heating rate increases and the duration of heat treatment is reduced by 5–10 times compared to surface heating, burning of products is excluded, the nutritional value of the product is more fully preserved, and the yield of finished products increases [13]. Processing in the microwave field of ready-made flour confectionery and bakery products inhibits the activity of moldy microflora, which allows to increase the shelf life of the products [14].

Conclusions. The studied data on the use of microwave energy in various technological processes allow us to talk about the effectiveness of this physical method of processing products. The use of microwave heating, as well as its complex with other physical methods and energy carriers, allows you to intensify technological processes, reduce the cost of finished products, as well as increase the nutritional and biological value of raw materials, semi-finished products and finished products. At the same time, the mechanisms of the influence of microwave energy on food products remain unexplored.

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