Complex Use of Various Types of Energy in Processes of Food Production and Storage

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Abstract. In order to improve the technological equipment of the food industry the issues of the development and application of innovations in food production are considered. The effects of the use of traditional types of energy and physical and mechanical fields in the production, storage and transportation of food are analyzed. Particular attention is paid to the complex effects of fields with various nature on technological processes. New principles of the development and production of technological equipment based on the synergy of heat, ultrasound, vacuum, pressure, electromagnetic effects, mechanical vibration are proposed. To estimate the effect of the integrated use of various types of energy in the preparation and storage of food products, a synergy coefficient has been introduced and justified. The results of theoretical and experimental studies of the complex effect of various types of energy on the initial components of food products and their production processes are presented in the form of graphs. The assessment of the effects of the integrated application of vepol technologies, allowing to increase the efficiency of technological equipment, productivity, to reduce energy costs, increase the usable shelf life of products, make it safer and better.

1. Introduction
The basis of modern food production technologies in the food industry is the deep processing of raw materials (even waste-free). It’s not feasible without the use of a variety of physical effects on the starting components. In this regard, non-waste processing of food raw materials, production and storage of wholefood requires the improvement and modernization of existing technological equipment. Increasing the operational parameters of technical means of the food industry is possible due to the effective use of various types of physical effects, the use of various types of energy (physical and mechanical fields) in the process of production, storage and transportation of wholefood.

2. Relevance and scientific importance
Last years we can see a significant increase of new samples of technological equipment based on the use of electromagnetic, thermal, ultrasonic and other types of effects on the starting components in the production of wholefood. Currently, steam ovens, hot grills and other equipment are widely used. Modernization of existing and the development of new types of equipment and technologies for food production can significantly expand their range, as well bakery products and bakery wares of original recipes.
At the same time, despite the appearance of a large number of new technologies and the introduction of new technical means, the cooking time and baking time of bakery wares didn’t significantly decrease, and the coefficient of performance (COP) of ovens in the food industry remains low (from 13 to 42%). The task of intensifying the processing of food raw materials, cooking, baking and reducing energy consumption, as well as increasing the efficiency of ovens and machines, remains relevant [1]. One of the ways to solve this problem is the possibility of using integrated vepol technologies in order to increase the efficiency of processing raw materials and producing wholefood.

3. Problem statement
The study of the efficiency of the distribution and contribution of energy to the food processing under the combined effects of several fields with different nature is one of the main directions of modernization of food industry maintenance. However, it should be noted that in the overwhelming majority of cases, the modernization of the maintenance was based on the results of experimental studies. Theoretical studies of the complex effect of various types of energy on the initial components of wholefood and the processes of their production and transportation have been insufficiently performed.

From the point of view of an objective explanation of the effect of field energy on food raw materials and wholefood, it is necessary to provide that vepol technologies in the food industry that take into account both the influence of the earth's fields and a complex of artificially created ones [2]. The concept of “wild-field technology” is broader than electrophysical technology. This is the synergy of the effects of fields of different nature (Figure 1) on the speed and quality of technological processes of processing food raw materials and semi-finished products.

At the same time, in the construction of technologies the synergistic effect of several additional artificial fields and their ability to enhance the qualitative parameters of the processes of production, storage and transportation of food are rarely used. Existing technologies include the production and storage of food using maximum two fields. Technological processes based on the simultaneous use of three or more artificially superimposed fields, taking into account their synergy, have been studied insufficiently.

![Figure 1. Fields affecting the processes of accelerating the processing of raw materials and food production.](image)

The optimization of technological processes, performed under the influence of several fields requires the development of new methods for calculating cooking time, nutritional value, safety and other qualitative characteristics of food products. It should be noted that the energy consumption for the creation of artificial fields is insignificant than the main energy consumed by technological equipment [3].

For example, processing fish in a magnetically activated brine, with the addition of iron chloride (FeCl₂) accelerates its salting process by 30–60% autolysis by 2 times and stops the development of microorganisms, which allows its storage without refrigeration equipment [4].

The use of electrothermal heat transfer and the creation of a protective thermal curtain on the heating surface of an electric stove reduces the consumption of thermal energy by 30–32% with standard indicators of the time for boiling water in a boiler. The additional energy costs for air ionization and the creation of thermal protection do not exceed 2-3% [5].

In the process of processing raw materials and food production using several fields, the rate of chemical and biological reactions changes significantly. Mechanical and acoustic vibrations, the application of electric and magnetic fields in combination with traditional cooking, drying, freezing, as well as chemical and biochemical processes significantly contribute to improving the efficiency of food preparation and their quality. Based on the studies [6, 7, 8], it can be argued that the combined use of a magnetic field, ultrasound and infrared radiation of a narrow range can significantly increase the efficiency of production of finished dishes. The effect of the electric field on the gas combustion process significantly increases the heat transfer to the gas stove cookers. The positive effects of using vepol technologies are presented in Figure 2.

So, the process of boiling water is accelerated by reducing gravity, which reduces the convective component, gravity, accelerates the convection process and provides a reduction in the time of heating the liquid and air. A prerequisite for baking bread in an oven is to maintain a stable temperature, providing dextrinization and gelatinization of the dough. The application of an ultrasonic field in addition to the thermal field allows one to reduce the thermal resistance of the air layer attached to the bread roll.

![Figure 2. Positive effects of using vepol technologies.](image)

It makes possible to bake bread while lowering the temperature inside the oven, and to reduce energy consumption. The action of ultrasound significantly intensifies heat transfer and mass transfer, so heating and evaporation are accelerated. It takes 1–2% of the power consumed by the furnace to obtain ultrasound. At the same time, the baking speed increases by 12–20% without reducing the quality indicators of the finished product.

Studies [9, 10, 11, 12, 13, 14] experimentally established the degree of participation of conditional fields in the processing of food raw materials and food products. Each field contributes to the intensification of food production.

The studies of cavitation processes have shown that when the bubbles collapse, a powerful local electric potential is formed, which transforms into a corona discharge, luminescence, and other effects. When the bubbles are evacuated, numerous cumulative streams of water are formed with a diameter of 0.1 - 1.0 mm. Their speed at the beginning of the exit from the cavitating bubble reaches 170 - 300 m/
s. The electrons of the atoms of the jet, interacting with the Earth's magnetic field, induce an EMF and a counter magnetic field.

In addition, a spherical shock wave forms, propagating at a speed of about 1500 m/s. Therefore, food will be cooked faster and more efficiently, and the rate of increase in broth concentration has a jump with the onset of boiling. Similar phenomena occur during the simplest mechanical cutting of a product or other mechanical action (shock, sound, vibration, mixing, etc.). The application of a mechanical field leads to the local movement of electrons and matter in the Earth's magnetic field, and to the appearance of induced highly effective conditional fields (magnetic, electric, thermal, etc.). The movement of atoms and molecules in the place of the cut forms initiates thermochemical, chemical, and electrochemical fluctuation reactions. It follows that even the most low-effective mechanical field at the point of its application with appropriate resonance imposition can exceed the strength of chemical bonds in molecules, changing the state of the product.

4. Practical importance

Particular interest during the study of conditional fields is the reversibility of one field to another. The impact on a substance (product) with a field with more significant parameters (for example, a constant magnetic field with a force two orders of magnitude greater than the Earth's) significantly changes the properties of the liquid in food. Even a short-term application of a constant magnetic field makes serious changes to the technological process of cooking food, drying products, fermenting dough, vegetables and wines, defrosting meat and fish.

The considered features of vepol technologies and the mutual influence of fields of various nature on food production makes it possible to take into account such an effect on the speed of cooking and its quality characteristics through the synergy coefficient \( A_n \). In the process of production, transportation and storage, it is important to be able to apply methods of changing this coefficient. So when storing foodstuffs and raw materials in the food industry for a long time they have been using vacuum, lowering the temperature, eliminating the effects of wave energy (ultraviolet, light, vibration), however, these factors are most often taken into account empirically in the calculations.

Let us consider the complex effect of artificial fields on improving the efficiency of technological processes in the processing of food raw materials, preparation and storage of wholefood. To this end, we firstly analyze the nature of the influence of the electric field on the technological processes of cooking (Figure 3).

As can be seen from the graph in Figure 3, with increasing the electric field strength, the boiling time of water and the amount of carcinogenic substances formed decrease, so the heat transfer and the efficiency of the thermal blocks increase.

**Figure 3.** Dependence of the operation parameters of thermal blocks on the effect of an electric field on the gas combustion process.
Increasing the voltage at the electrodes provides an increase in the temperature of the frying floor and heat transfer, as well as a decrease in the consumption of gas fuel and its chemical underburning (expressed in the content of carbon monoxide in flue gases).

The imposition of an ultrasonic field during the drying of semi-finished pasta products with additives ensures a reduction in their production time and humidity, and also increases the compaction of the mass of finished products and their resistance to fracture, which are important indicators in the production of pasta with high nutritional value.

Infrared radiation affects the reduction of microorganisms during grain processing [14].

The effect of infrared radiation on whole grains in the process of preparing it for grinding ensures a 2-fold reduction in the number of mesophilic-aerobic microorganisms, and a 1.5-fold decrease in molds.

The magnetization of water, used for container preparation provides increasing of productivity and reducing the number of microorganisms on the walls of the container.

The effect of electro-hydraulic shock on the quality indicators of grain processing products is shown in Figure 4 [15]. The increase in pressure during electro-hydraulic shock (Fig. 4) during the grinding of grain into flour and dusts ensures a reduction in energy consumption, contamination by microorganisms and molds, and also allows you to save the nutritional value of the feedstock and increase the nutritional value of the finished product.

![Figure 4](image.png)

**Figure 4.** Dependence of the influence of electro-hydraulic shock on the quality indicators of grain processing products.

The use of the considered fields separately allows us to improve some quality indicators, preserve the nutritional value of the feedstock and reduce the time of production (preparation) of finished products [16-21].

In the process of food production using vepol technologies, it is important to study the synergistic effects of the complex effects of several fields on the processing of raw materials, production and storage of wholefood. In this case, it is necessary to develop methods for assessing the compatible effect of fields on these processes through the synergy coefficient.

The synergy coefficient An should be understood as the degree of the complex effect of the induced fields on the intensity of the processes associated with the preparation and storage of food products. The value of this coefficient should be expressed in fractions of units or percent.

The given dependence takes into account the synergistic effect of field interaction, which consists in the fact that the complex controlled effect of fields of different nature on a substance is energetically
and economically beneficial. In addition, the use of vepol technologies for the preparation and storage of food products improves the marketability and taste of food products.

5. Conclusions

Thus, the use of vepol technologies in the design of technological equipment will increase the efficiency of technological processes for processing raw materials, production, storage and transportation of wholefood, convert a significant portion of the product that is not digestible into nutritious, digestible (cellulose into starch and sugar, cartilage and tendons into collagen, sparingly soluble and coloring matter in solutions, etc.), reduce or completely abandon preservatives, bleaches, dyes, disintegrants, stabilizer moat, surfactants and other additives, thereby improving the environmental quality and food safety.

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